DOCUMENT RESUME

ED 227 214 CE 032 984

TITLE [Electricity: Safety and Vocabulary, Wiring, and Motors.] Student Materials. V.A. III. [V-A-1 through V-A-5].

INSTITUTION Texas A and M Univ., College Station. Vocational Instructional Services.

PUB DATE [80]

NOTE 52p.; For related documents, see CE 032 968, CE 032 975, CE 032 978, CE 032 980, CE 032 987, and CE 032 989-990.

PUB TYPE Guides - Classroom Use - Materials (For Learner) (051)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.

DESCRIPTORS Agricultural Education; Agricultural Engineering; Definitions; Electric Circuits; *Electricity; *Electric Motors; Electronic Equipment; Energy; Equipment Maintenance; Equipment Utilization; *Farm Management; *Safety; Safety Equipment; Secondary Education; Vocational Education

IDENTIFIERS Electrical Production; *Electrical Wiring; Energy Consumption

ABSTRACT

Designed for use in vocational agricultural classes, this student manual deals with the use of electricity. The first section gives vocabulary words and safety instruction. Other sections contain information on wiring and motors. A quiz on the materials covered concludes the booklet. (PLB)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

TX 501330X

V. A. III
V-A-1

"PERMISSION TO REPRODUCE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY

Page

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

This document has been reproduced as received from the person or organization originating it.

Minor changes have been made to improve reproduction quality.

Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

ELECTRICAL SAFETY & TERMS

The use of electricity is so commonplace that most people assume that it will always be available on demand. To fully realize the dependence upon electricity, survey the ways electricity is being used each day in the home and on the farm and ranch. Electricity is doing more to increase work efficiency and promote enjoyable living than any other single factor. The use of electricity has grown to the extent that an increasing portion of the home or business budget is used in paying for this source of energy.

ED227214

1. DEFINITION OF ELECTRICITY

Electricity can be defined in several ways. The layman defines electricity as a source of energy that can be converted to light, heat, or power. Electrical engineers define electricity as a movement of electrons caused by electrical pressure or voltage. The amount of energy produced depends on the number of electrons in motion.

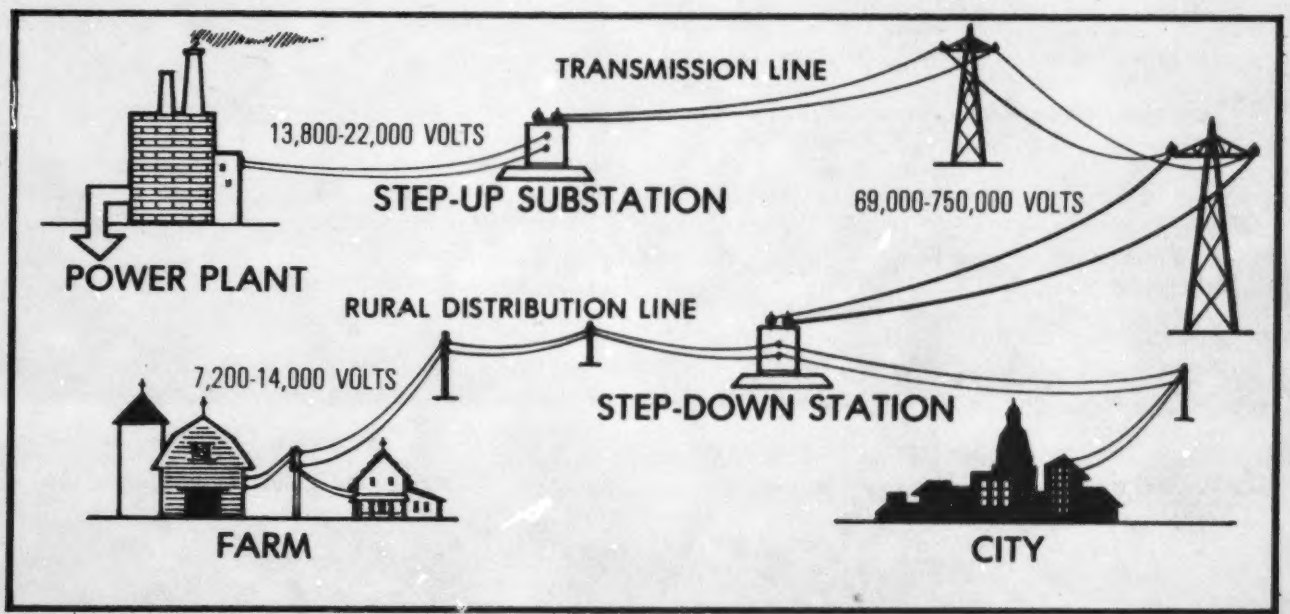
2. THE MANUFACTURE AND DISTRIBUTION OF ELECTRICITY

Electricity is produced from generators that are run by water, steam, or internal combustion engines. If water is used as a source of power to turn generators, it is referred to as hydroelectric generation. There are a number of this type located in areas where huge dams have been built across large streams.

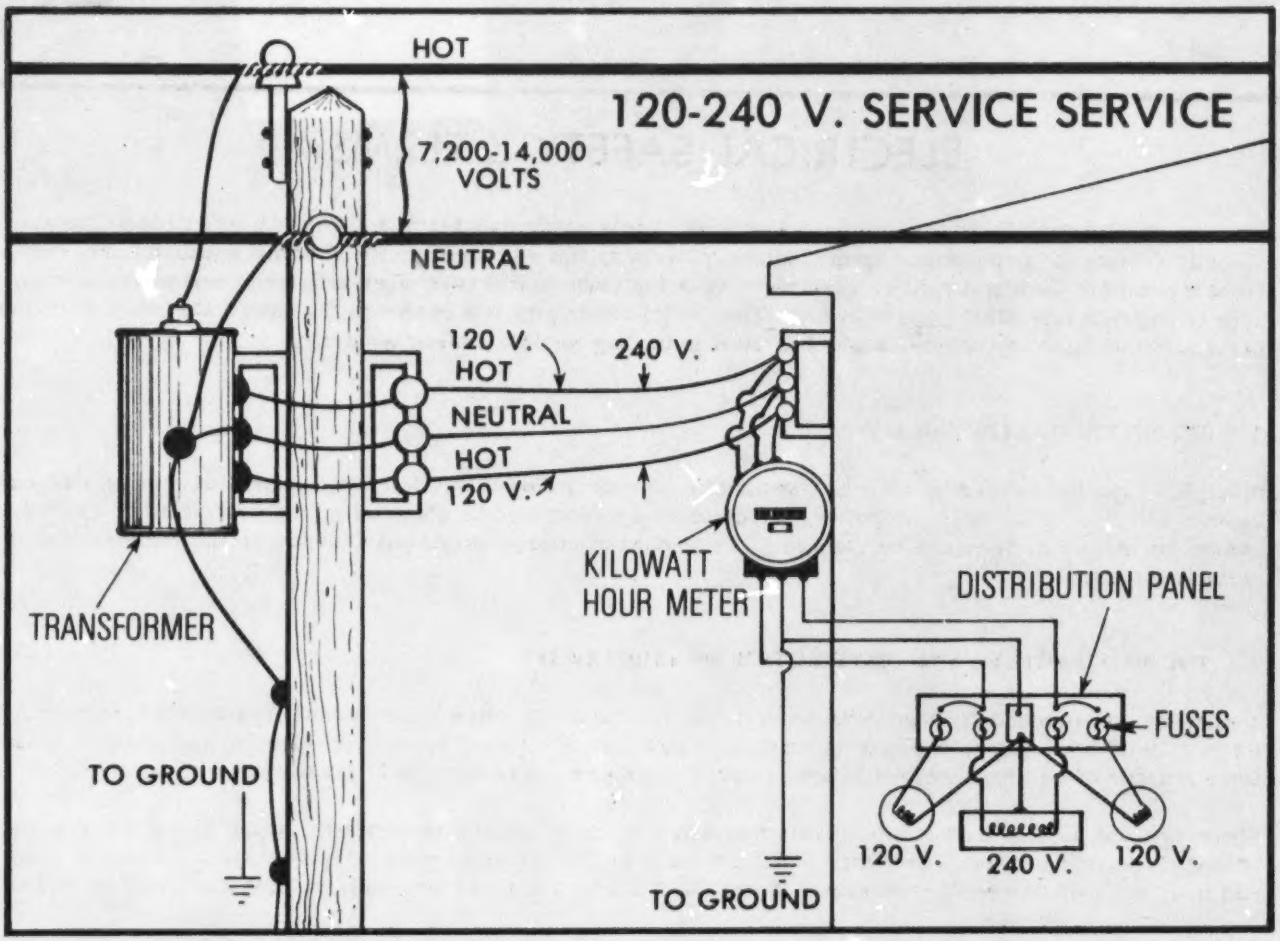
Steam is used as a source of power for generating much of today's electricity. Water is heated to a high temperature, and the steam pressure is used to turn turbines which generate electricity. These are referred to as thermal-powered generators. Fuels used to heat the water are coal, natural gas, and/or fuel oil.

Generators at the power plant generate from 13,800 to 22,000 volts of electricity. From the power plant, electricity is carried to a step-up substation which, through the use of transformers, increases the voltage from 69,000 to 750,000 volts. This increase in voltage is necessary for the efficient transmission of electricity over long distances. From the step-up substation, the electricity is carried on transmission lines to a step-down substation which reduces the voltage to 7,200 to 14,000 volts for distribution to rural and city areas.

ED329894



Transformers at the farm or home reduce the voltage to 120 or 240 volts to the meter of the customer.



3. COMMON ELECTRICAL TERMS

In order to work safely and efficiently with electricity and have the ability to converse on the subject, the following terms should be understood:

Ampere (Amp) - A measurement in units of the rate of flow of electricity. This may be compared with the rate of flow of water in gallons per minute.

Example: A 60-watt incandescent lamp on a 120 V circuit would pull 1/2 ampere of electricity.
Formula: Amp = Watts ÷ Volts

Volt (V) - A unit of measure of electrical pressure. A given electrical pressure (V) causes a given amount of electrical current (Amps) to flow through a load of given resistance. Voltage may be compared with water pressure in pounds per square inch in a water system. Common service voltages are 120 volts for lighting and small appliance circuits and 240 volts for heating, air conditioning, and large equipment circuits.

Watt (W) - A unit of measure of electrical power. When applied to electrical equipment, it is the rate that electrical energy is transformed into some other form of energy such as light. Watts may be compared to the work done by water in washing a car. (Formula: Volts x Amps = Watts).

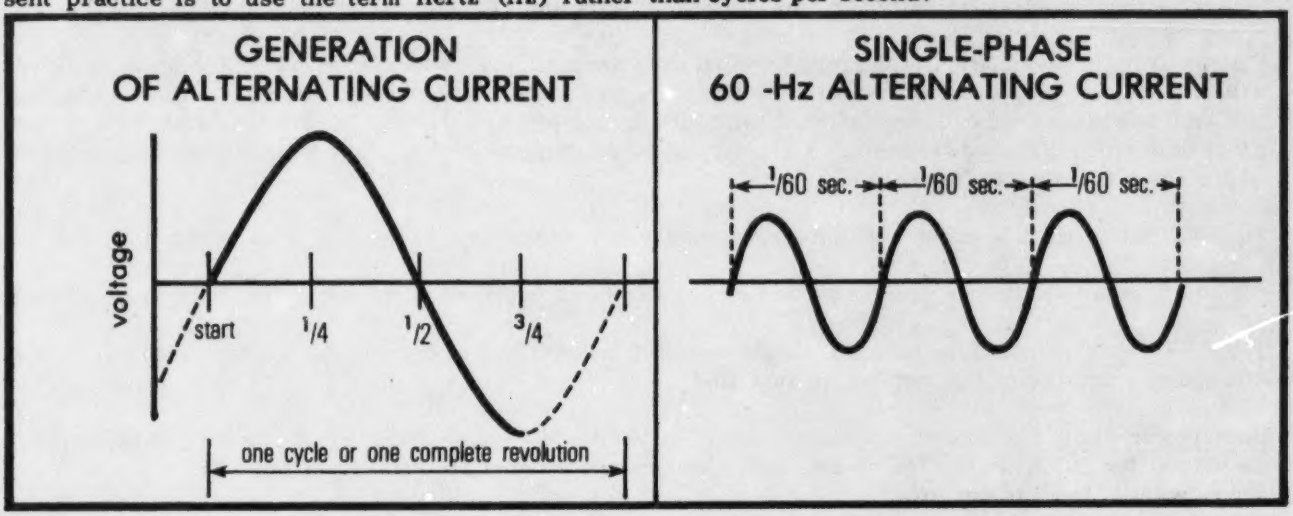
Kilowatt (KW) - A unit of measurement used in computing electrical energy used. Kilowatts are determined by dividing the number of watts by 1000. (1 KW = 1000 W)

Kilowatt - hour (KWH) - A measure of electricity in terms of power in kilowatts and time in hours. A KWH is 1000 watts used for one hour.

Alternating Current (A.C.) - Electrical current that alternates or changes direction several times per second. The direction current moves depends on the direction the voltage forces it.

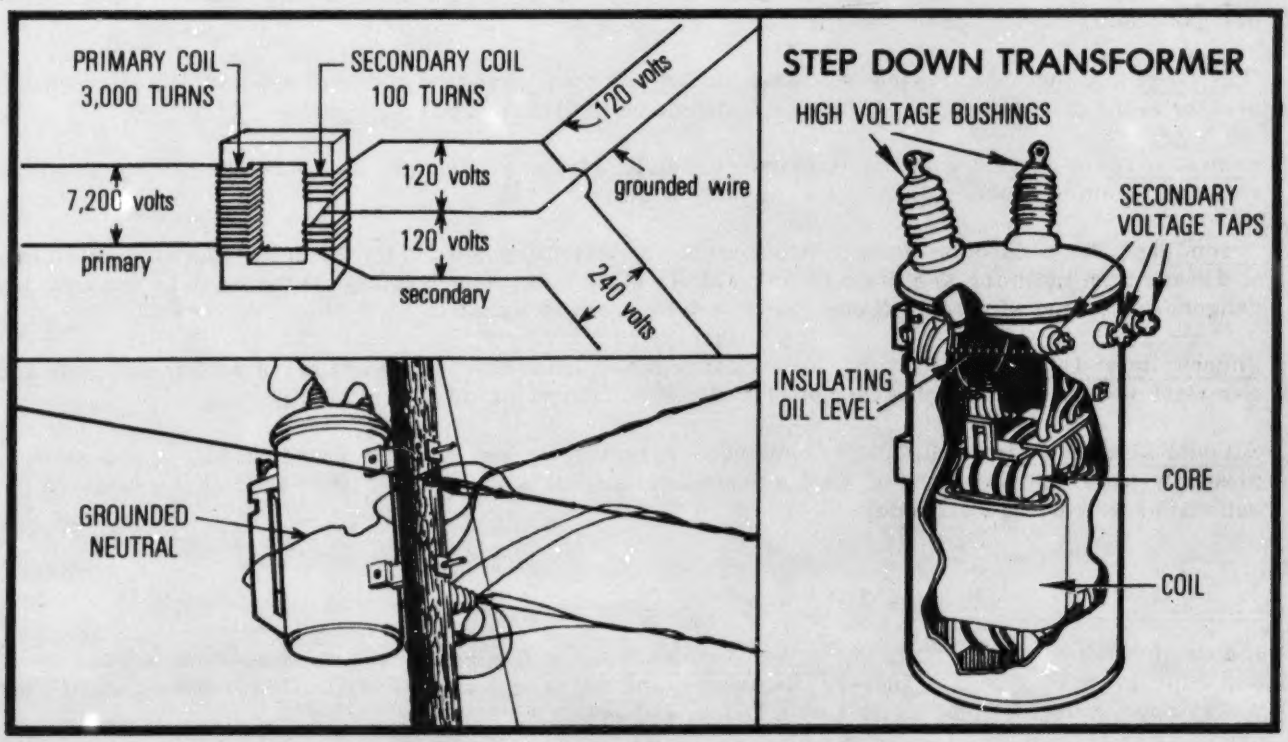
Cycle - The flow of electricity in one direction, the reverse flow of electricity in the other direction, and the start of the flow back in the other direction.

The cycles per second are regulated by the power supplier and are usually 60. Most electric clocks are built to operate on 60 cycles. More or less cycles would cause the clocks to gain or lose time. The present practice is to use the term Hertz (Hz) rather than cycles per second.



Direct Current (D.C.) - Electrical current flowing in one direction. Example: electrical circuit in an automobile or tractor.

Transformer - A device used to increase or decrease voltage.



Single - Phase - The most common type of electrical service or power available to farms and homes. One transformer is used between the distribution line and the meter. Usually three wires, two "hot" and one neutral, are installed to provide 120 V and 240 V single-phase service. Single-phase service may also be supplied with three-phase service.

Three - Phase - This type of service is designed especially for large electrical loads. It is a more expensive installation due to three wires and three transformers. The important advantage of three-phase power is that the total electrical load is divided among the three phases; consequently, the wire and transformers can be smaller. Other advantages exist in the design of three-phase motors.

Short Circuit - A direct connection (before current flows through an appliance) between two "hot" wires, between a "hot" and neutral wire, or between a "hot" wire and ground.

Voltage Drop - A reduction of current between the power supply and the load. Due to resistance, there will be a loss of voltage any time electricity flows through a conductor (wire). Factors that influence voltage drop are size of wire, length of wire, and the number of amps flowing. A drop in voltage may cause a loss of heat, light, or power output of a motor. It could cause motor burn-out unless the motor is properly protected (time-delay fuse).

Fuse - A device used to protect circuits from an overload of current.

Circuit Breaker - A device used to protect circuits from an overload of current. May be manually reset.

Time - Delay Fuse - A fuse with the ability to carry an overload of current for a short duration without disengaging the contacts or melting the fuse link.

Horsepower (hp) - A unit of mechanical power equal to 746 watts of electrical power (assuming 74.6% electric motor efficiency). One hp and above motors are rated at 1000 watts per hp; motors below one hp are rated at 1200 watts per hp.

Conductor - The wire used to carry electricity (copper or aluminum). Copper and aluminum should not be spliced together due to their incompatibility resulting in deterioration and oxidation.

Insulator - A material which will not allow electricity to pass through and is usually made of glass, bakelite, porcelain, rubber, or thermo-plastic.

"Hot" Wire - A current-carrying conductor under electrical pressure and connected to a fuse or circuit breaker at the distribution panel. (Color Code: usually black or red)

Neutral Wire - A current-carrying conductor not under electrical pressure and connected to the neutral bar at the distribution panel. (Color Code: usually white)

Grounding - The connection of the neutral part of the electrical system to the earth to reduce the possibility of damage from lightning and the connection of electrical equipment housings to the earth to minimize the danger from electrical shock. (Color Code: can be green or bare wire)

Underwriters' Laboratory (U.L.) - A national organization which tests all types of wiring materials and electrical devices to insure that they meet minimum standards for safety and quality.

National Electric Code (N.E.C.) - Regulations approved by the National Board of Fire Underwriters, primarily for safety in electrical wiring installations. All wiring should meet the requirements of the national as well as the local code.

4. COMPUTING ELECTRICAL ENERGY USE AND COST

If a rough estimate of electricity use and cost is desired, the name plate data on appliances and equipment and an estimate of operating time may be used. The following formulas should be used for determining watts, amps, volts, watt-hours, kilowatt-hours, and cost.

WATTS = VOLTS x AMPERES

$$\text{AMPERES} = \frac{\text{WATTS}}{\text{VOLTS}}$$

$$\text{VOLTS} = \frac{\text{WATTS}}{\text{AMPERES}}$$

WATTS x HOURS OF OPERATION = WATT-HOURS

$$\text{KILOWATT-HOURS} = \frac{\text{WATT-HOURS}}{1000}$$

COST = KWH x LOCAL RATE PER KWH

Example cost problem:

LOCAL RATE PER KWH USED - 6¢

NAME PLATE DATA - 120 VOLTS 5 AMPS

MONTHLY HOURS OF OPERATION - 8

(1) (W = V x A) W = 120 x 5 W = 600

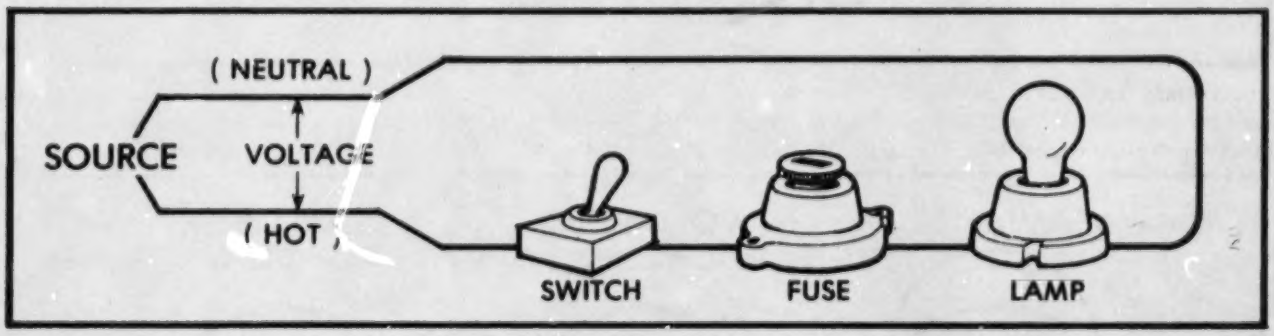
(2) (WATT-HOURS = W x HOURS) WATT-HOURS = 600 x 8 WATT-HOURS = 4800

(3) $\left(\text{KWH} = \frac{\text{WATT-HOURS}}{1000}\right)$ $\text{KWH} = \frac{4800}{1000}$ KWH = 4.8

(4) (COST = KWH x RATE) COST = 4.8 x 6¢ COST = 28.8¢

5. ELECTRICAL CIRCUITS

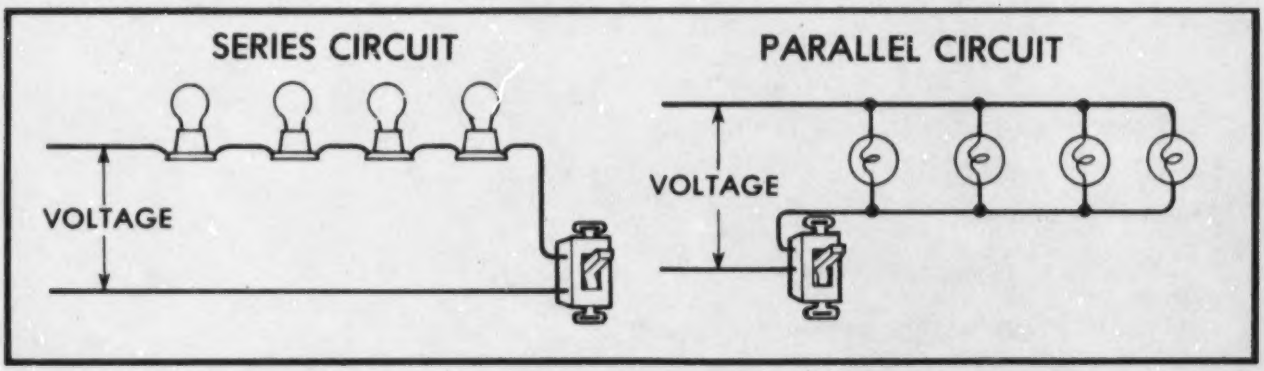
An electrical circuit is a completed path through which electricity flows. Insulated conductors (wires) provide the path for the flow of electricity. A water system and an electrical circuit are similar in many respects. Water flows through pipes and is measured in gallons per minute, and electricity flows through conductors and is measured in amperes. A simple circuit is diagrammed here:



A circuit includes a "hot" wire (red or black) carrying current from the source through a switch, circuit protector (fuse or circuit breaker), and an appliance. The neutral wire (white) conducts the current from the appliance to the source (ground).

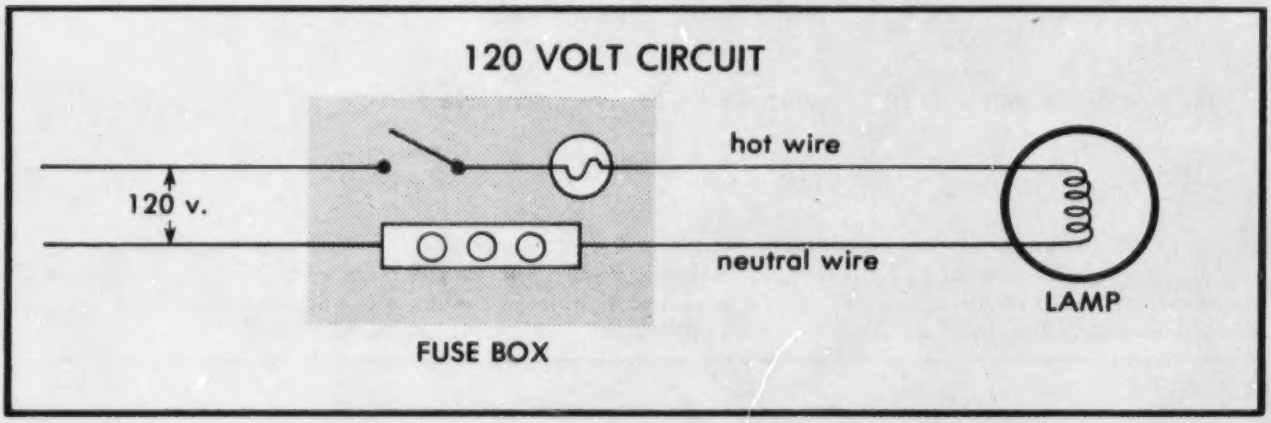
There are two methods for connecting devices in a circuit-series and parallel. In a series circuit all the current must flow through each device in the circuit. Removing or opening any one of the devices in the series circuit will stop the flow of current. In parallel circuits the load (lights or appliances) are connected between the two wires of the circuit providing an independent path for the flow of current, and removing a lamp has no effect on the other lamps in the circuit.

Switches, fuses, and circuit breakers are always connected in series. In most cases, except for Christmas tree lights, appliances and lights are connected in parallel.

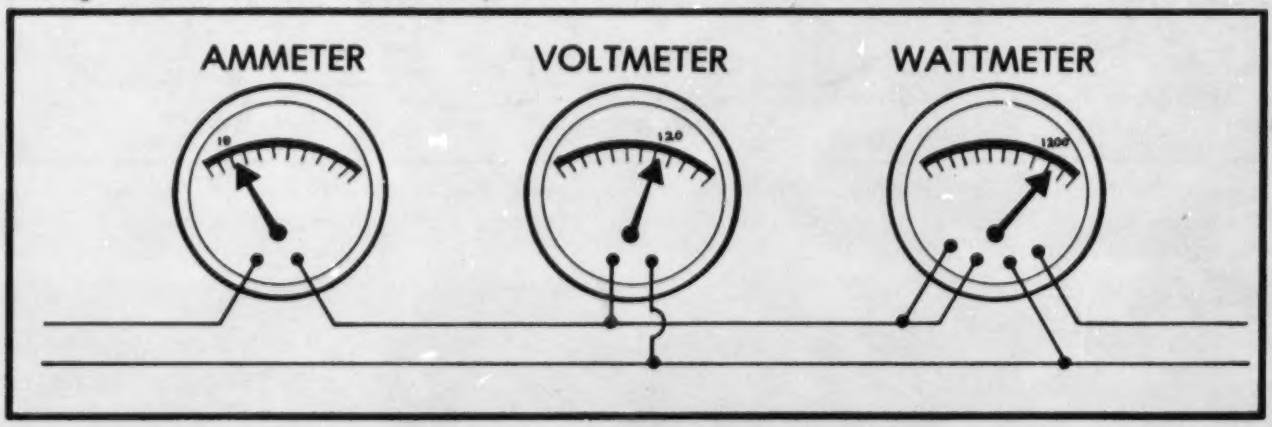


6. 120 VOLT AND 240 VOLT CIRCUITS

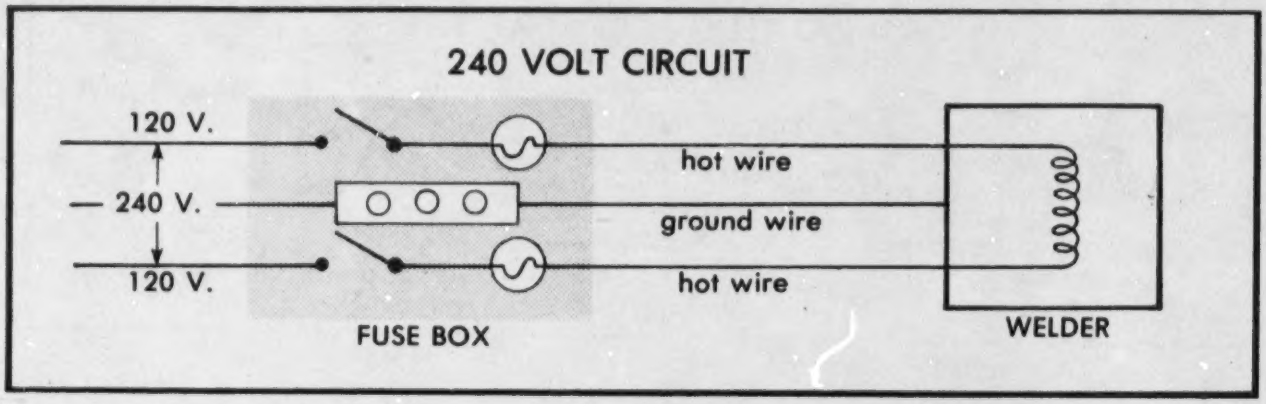
The 120 V circuit has one "hot" and one neutral wire with the switch and circuit protector in the hot line. The neutral wire from the appliance is connected to the neutral bar in the fuse or breaker box. For safety, the neutral wire should never be broken or interrupted with a switch or fuse.



The voltage in a 120 V circuit is measured with a voltmeter with one lead on the hot terminal and the other lead on the neutral bar. The number of amperes flowing may be measured with a clamp-on ammeter by encircling the hot or neutral wire with the jaws of the ammeter.



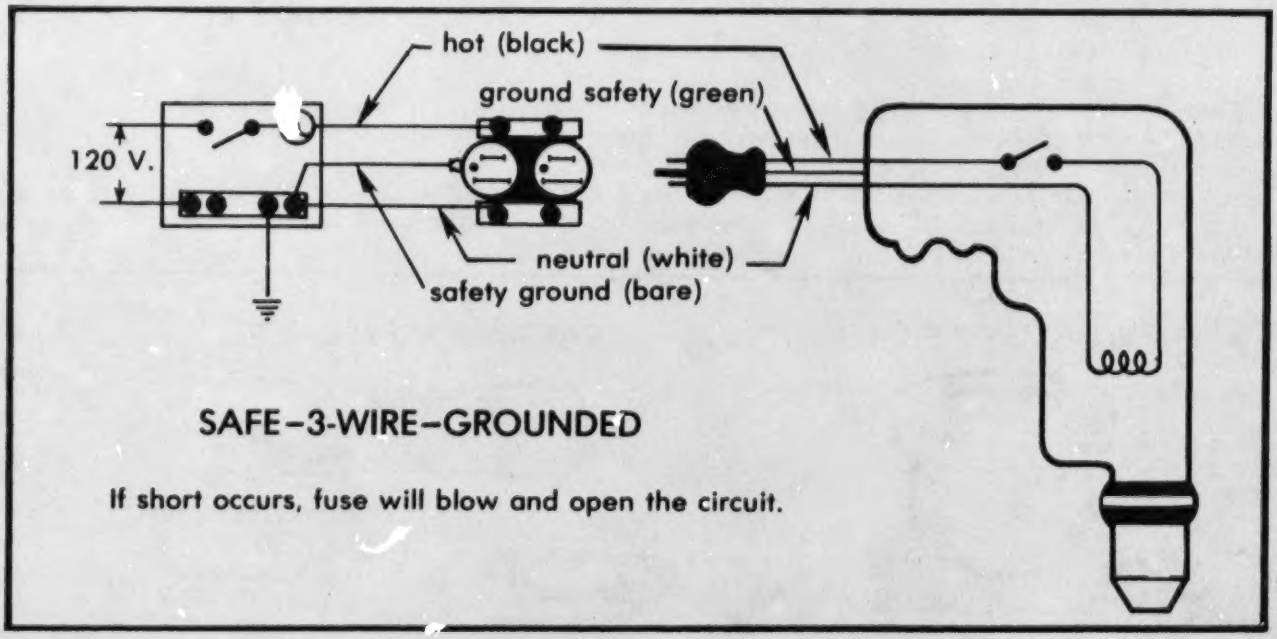
The 240 V circuit has two hot wires and one safety-ground wire. Switches and fuses are installed in the hot lines. The two hot wires are necessary for the operation of 240 V welders and motors. The safety-ground wire, connected to the metal frame and to the neutral bar, does not carry current unless a "short" develops in the motor or welder. If a short should occur, one of the circuit protectors will burn-out or open, thus opening the circuit.



The voltage on a 240 V circuit is measured by fastening a lead on the voltmeter to each of the hot wires. Voltage between either hot terminal and the neutral bar will be one-half of the voltage between the two hot wires. The number of amperes flowing can be measured by clamping a clamp-on ammeter around either of the hot wires.

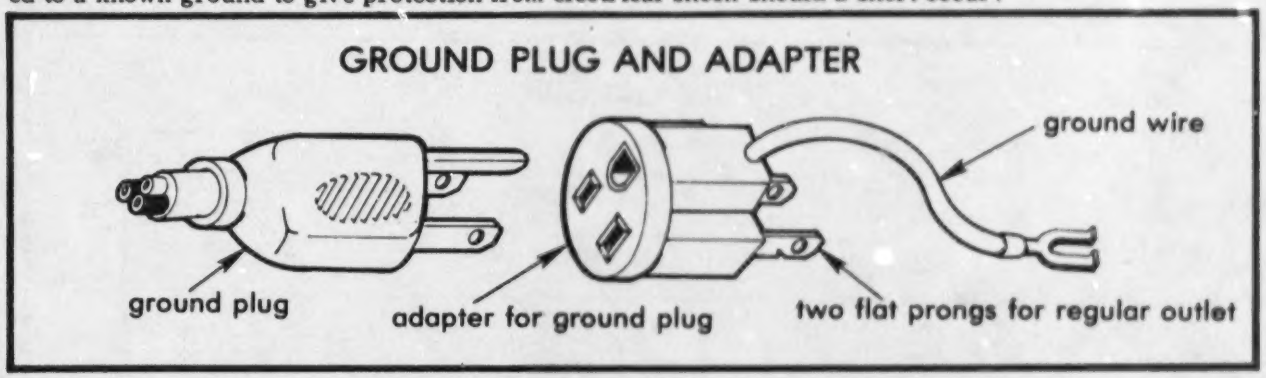
7. SAFETY GROUNDING ELECTRICAL EQUIPMENT

Refer back to the 240 V circuit and note the ground wire from the metal frame to the neutral bar. The following illustration shows proper safety grounding when operating a drill in a 120 V circuit.



The safety-ground wire may be bare, but a three-wire romex is recommended. Safety-ground wire in three-wire romex is usually green in color. A current-carrying neutral should never be used for a safety-ground. Likewise, a safety-ground wire should never be used as a current-carrying hot or neutral wire.

Using grounded receptacles and a safety-ground on all circuits will allow the safety-grounding of appliances when they are plugged into the outlet. An adapter must be used to properly ground appliances connected to receptacles not safety-grounded. If an adapter is used, the green pigtail wire must be connected to a known ground to give protection from electrical shock should a short occur.



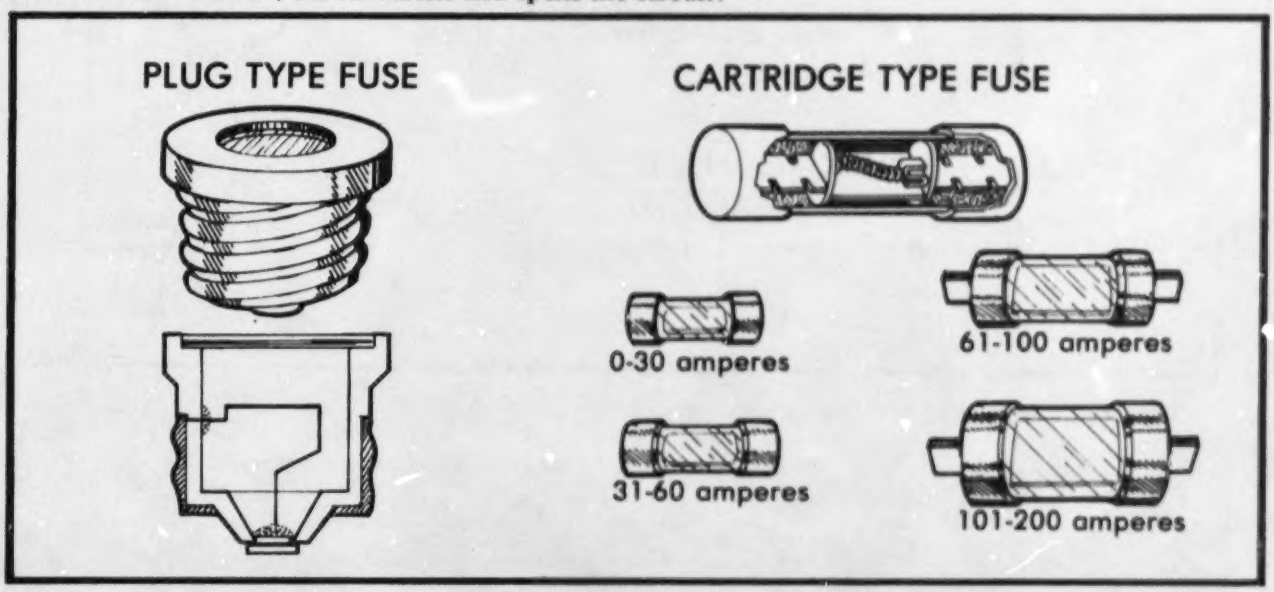
A test lamp can be used to check a circuit completed between a "hot" wire and a neutral wire. Use the test lamp to check appliances for shorts. With the appliance plugged into an outlet, touch the appliance frame with one lead of the test lamp while the other lead of the test lamp is grounded to a water or gas line. If the test light does not burn, reverse the appliance plug and check with the test lamp again. If the light burns, a short exists. (Hot wire is touching the frame of the appliance.) Unplug the appliance and repair or discard it.

8. ELECTRICAL CIRCUIT PROTECTION

Electrical circuits should be protected from an overload of amperes. Too many amperes flowing through an unprotected circuit will generate heat, which will deteriorate or melt the insulation and possibly cause a fire. The number of amperes that a given conductor can carry safely depends upon the kind and size of wire, type of insulation, length of run in feet, and type of installation. Charts are available in reference texts giving allowable current-carrying capabilities of various conductors.

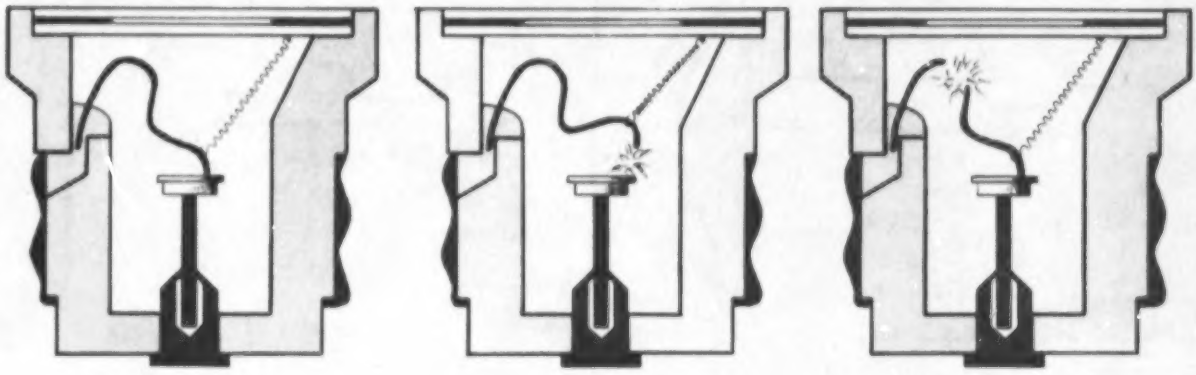
The four types of circuit protection are common fuses, fusetrons (time-delay), fustats (two-part time-delay), and circuit breakers. Fuses are of two basic types, plug and cartridge.

Common fuses contain a link made from a low melting alloy which is designed to carry currents up to the rating of the fuse. Current higher than the amperage rating causes the link to heat above its melting point. When the fuse "blows", the link melts and opens the circuit.



Fusetrons (time-delay fuses) are made to carry a temporary overload, such as the overload caused by the starting of an electric motor. The fuse, however, still provides protection for the circuit, and a short circuit will melt the fuse link. If a common fuse is used, the fuse link will melt every time an electric motor starts. The use of a larger ampere common fuse will not provide protection for the motor or the circuit.

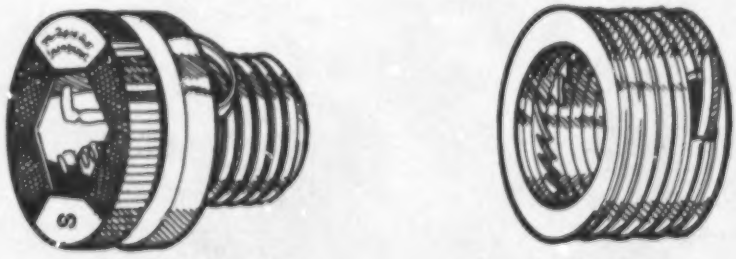
OPERATING PRINCIPLE OF DELAYED ACTION FUSE



TIME DELAY CONTINUED OVERLOAD SHORT CIRCIUT

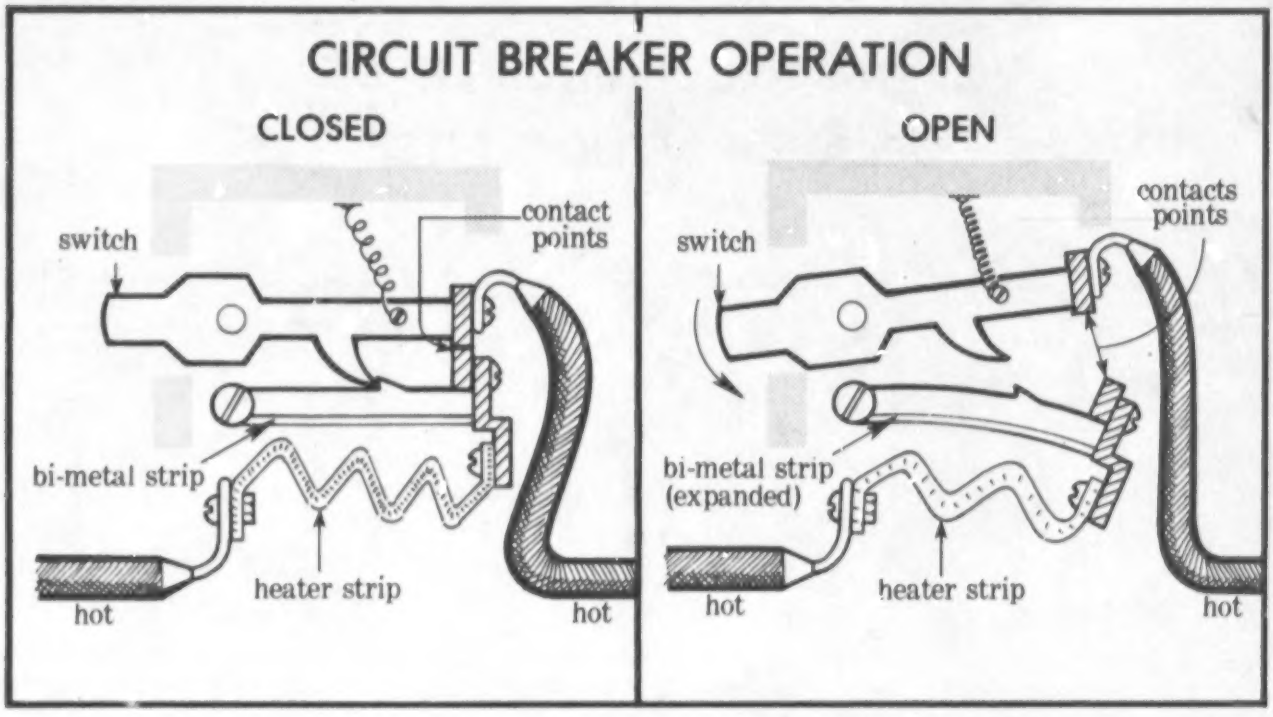
Fustats, nontamperable fuses of the time-delay type, have a different size base and require a special adapter that is screwed into the standard fuse socket. After the adapter is installed, it cannot be removed. For example, the installation of a 15-ampere adapter allows only the use of 15-ampere or smaller fuses.

FUSTATS



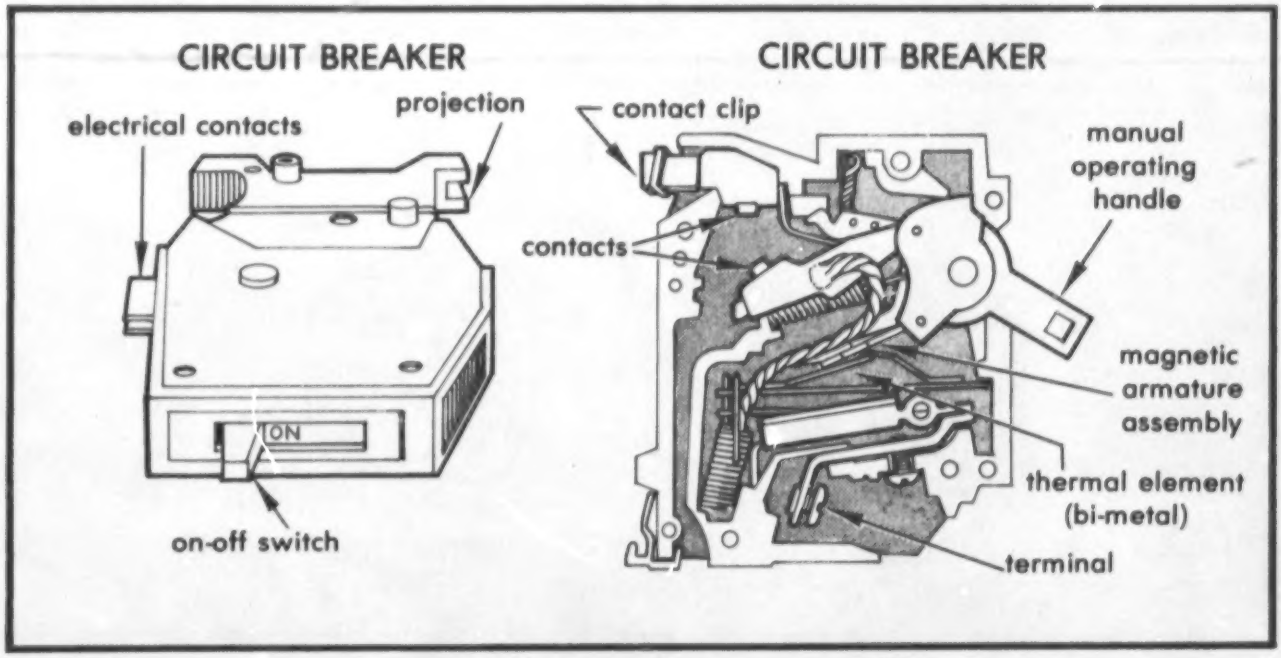
FUSE ADAPTER

Circuit breakers eliminate the replacement of fuses and are commonly used even though a circuit breaker box costs more than a fuse box. Circuit breakers are of two types, thermal and magnetic. The thermal breaker has two contacts held together by a bi-metal latch. An overload of current causes the bi-metal strip to become heated, the latch releases, and the points spring open. After the bi-metal strip cools, the switch is reset; and service is restored.



The magnetic breaker has contacts that are held together by a latch which is released by the action of an electromagnet. The amount of current flowing through the circuit will determine the size of the electromagnet. This type of breaker is reset by moving the toggle switch to the "on" position.

The following diagram shows the parts of a circuit breaker.



11

9. NO FAULT GROUNDING

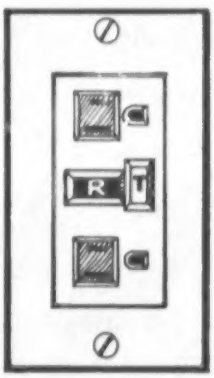
Fuses and circuit breakers are safety devices which limit current (amperage) in a circuit. Their main function is to protect equipment and wiring from overload. Ground fault circuit interrupters (GFI) are designed to protect humans, equipment, and/or electrical systems from injury or damage if electricity flows in an unintended path (a short).

A GFI is a very sensitive device that functions by comparing the current flowing in the "hot" wire with that in the neutral wire. If these two currents are not equal, a fault exists, and current is "leaking" out of the circuit. If the difference in current between the two wires is 5/1000 of an ampere or greater, the GFI will open the circuit, shutting off the power and eliminating any shock hazard.

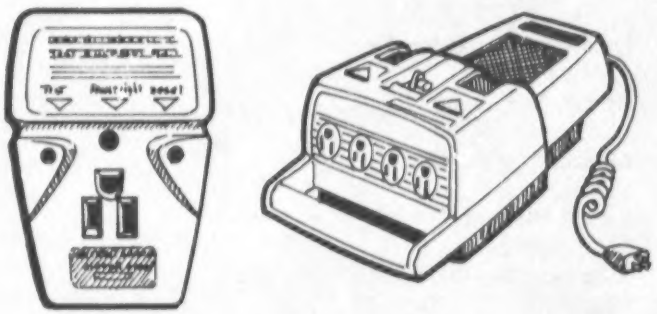
The National Electrical Code requires GFI's for all 120 V, single phase, 15 and 20 amp receptacles installed outdoors, in bathrooms, and in garages for residential buildings. A GFI is required at construction sites and some other applications. After correcting the circuit fault, the GFI may be reset for further use.

A variety of GFI equipment is made for 120 and 240 volt circuits.

GFI RECEPTACLE FOR CONVENTIONAL OUTLET

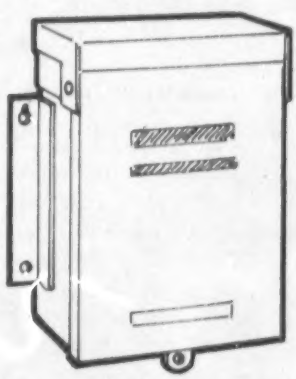


reset and test buttons

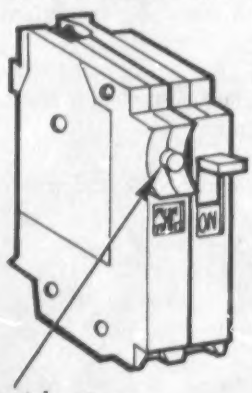


PORTABLE GFI TO PLUG INTO OUTLET

GFI TO INSTALL IN BRANCH CIRCUIT



GFI TO REPLACE CIRCUIT BREAKER



test button

SUGGESTED STUDENT ACTIVITIES

I. Fill in the blank.

1. _____ is a source of energy that can be converted into light, heat, or power.
2. Electricity is produced from generators that are run by _____, _____, or internal combustion _____.
3. Transmission lines carry electricity over long distances under pressures ranging from _____ to _____ volts.
4. _____ at the farm or home reduce the voltage to 120 or 240 volts to the meter of the customer.

II. Matching

_____	Measurement of the rate of flow of electricity.	A. N.E.C.
_____	Measure of electrical pressure.	B. Grounding
_____	Measure of electrical power.	C. Insulator
_____	1000 watts.	D. U.L.
_____	1000 watts used for 1 hour.	E. Horsepower
_____	Cycles per second.	F. Neutral Wire
_____	Alternating current.	G. Hot Wire
_____	Direct current.	H. Conductor
_____	A device that decreases voltage.	I. Fuse or Circuit Breaker
_____	A direct connection causing electrical current to flow in an unintended path.	J. Short Circuit
		K. Transformer
_____	A loss of voltage between the power supply and the load caused by resistance.	L. Voltage Drop
_____	A device to protect circuits from an overload of current.	M. D.C.
_____	A unit of mechanical power equal to 746 watts of electrical power.	N. A.C.
		O. Hertz
_____	The material carrying electricity (usually copper or aluminum).	P. Ampere
_____	A material that will not conduct electricity.	Q. Kilowatt
_____	A current-carrying conductor under electrical pressure.	R. Volt
_____	A current-carrying conductor not under electrical pressure.	S. Watt
		T. Kilowatt-hour
_____	The connection of the neutral part of the electrical system to the earth to reduce the possibility of damage or shock.	
_____	Underwriters' Laboratory.	
_____	National Electrical Code.	

III. Problem Solving

1. In a 120 volt circuit a portable saw pulls 10 amperes. What is the watt rating?

2. In a 120 volt circuit 5-200 watt light bulbs are in operation. What amperage is the circuit carrying?

3. If the 5-200 watt light bulbs in the above problem are used continously for eight hours, at the rate of 5¢ per KWH, what is cost of operation?

4. Sketch and lable a simple circuit.

IV. Discussion

1. Explain the difference between a 120 volt and a 240 volt circuit.

2. How does the series differ from the parallel circuit?

3. Discuss safety grounding electrical equipment.

4. Name and discuss the types of fuses.

V. True or False

_____ 1. Switches, fuses, and circuit breakers should always be wired in series in the "hot" wire.

_____ 2. Voltage may be measured by connecting the voltmeter to the "hot" wire or terminal.

_____ 3. When using an adapter with a ground plug, it is safe to attach the green pigtail ground wire to a cover plate screw in an ungrounded circuit.

_____ 4. Fuses are of two basic types, plug and cartridge.

_____ 5. Placing a penny behind a "blown" fuse is a safe practice.

_____ 6. Fusetrons and fustats are examples of time-delay fuses.

_____ 7. Circuit breakers must be replaced after the circuit has been overloaded.

_____ 8. Fuses and circuit breakers limit the amperage in a circuit; therefore, they protect the circuit from overload.

_____ 9. Ground fault circuit interrupters protect the circuit from damage and humans from injury when electricity flows in an unintended path.

___ 10. The National Electrical Code requires GFI's in all circuits in residential dwellings.

NOTES

ALL RIGHTS RESERVED

Reproduction prohibited without written permission.
Vocational Instructional Services
Texas A&M University
College Station, Texas 77843

TX 80 13308

V. A. III
V-A-2
V-A-3

STUDENT MATERIALS

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
This document has been reproduced as received from the person or organization originating it.
Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

"PERMISSION TO REPRODUCE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY
F Page
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

ELECTRICAL WIRING

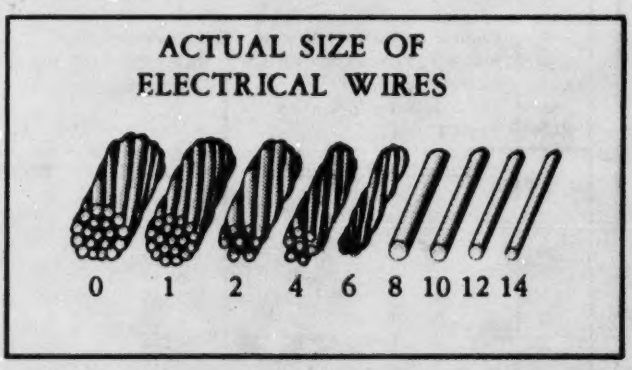
A well-planned wiring system must be safe, economical, adequate, and expandable. Conductors used in the system should be of a size that will carry the necessary amperage safely. Circuits must be fused properly and installed according to the National Electrical Code. The code insures safety but the other factors depend upon careful planning. An economical system is one that is safe, adequate, and efficient and can be acquired at a minimum cost.

To be adequate, a system should have sufficient voltage to operate all appliances with no more than a two percent voltage drop on lighting and heating circuits. There should be no more than a three percent voltage drop for motors. An adequate number of outlets and switches of the proper type and rating should be included in the system. Anticipated future electrical needs should be considered and allowances made for their installation.

1. WIRING MATERIALS

Wire size - The size of the conductor used for wiring is very important. A larger wire will safely carry more amperage, just as a larger pipe will carry more water than a smaller one with a given pressure. Attempting to force too much current through a small wire increases the resistance and drops the voltage, causing inefficiency in operation of electrical devices.

Electrical wires are numbered to indicate their size (gauge) according to the American Wire Gauge Standards. Small numbers indicate large wires, while large numbers indicate small wires.



Kinds of Wire - There are two kinds of wire, solid and stranded. They may be copper or aluminum. Aluminum wire is lighter in weight and requires approximately one size larger than copper wire to carry the same load in amperes. Stranded wire is made up of several small wires wrapped together. This provides more flexibility for the wire, particularly the larger sizes. Indoor wire larger than a No. 8 is generally stranded. A No. 6 stranded conductor is made up of seven smaller wires whose total cross-sectional area is the same as that of a No. 6 solid conductor.

Types of Wire - Outdoor wire is used for wiring between buildings and is usually covered with neoprene or polyethylene. The use of three-conductor self-supporting service drop wire is common. It consists of two insulated wires wrapped around a bare stranded wire which is used as the ground and supporting wire. The use of underground wire has increased in the last few years. This eliminates ice and wind damage. The elimination of overhead wires also adds to the attractiveness of the farm and home.

OUTDOOR WIRE TYPES		USES
UF	- underground feeder	Buried underground
USE	- underground service entrance	Mechanical protection required where they enter and leave ground
SE or SEU	- service entrance unarmored	To bring current into buildings
ASE	- armored service entrance	Same as SE

Indoor wiring is designed for use inside buildings; however, some types can be used both inside and outside. Special coatings have been developed for wires used inside buildings having excessive moisture. Most of the insulations used on inside conductors are made of fire and moisture resistant materials.

INDOOR WIRE TYPES		USES
T	- thermoplastic	Inside buildings
TW	- thermoplastic moisture resistant	In areas with moisture
RH	- rubber, heat resistant	Carry higher voltage than T or TW
RHW	- rubber, heat and moisture resistant	Service entrance or large appliance
NM	- nonmetallic cable (romex)	Inside buildings

Based on the National Electrical Code the following chart shows the allowable current-carrying (amperage) capacities of insulated copper and aluminum conductors:

ALLOWABLE AMPACITIES OF INSULATED WIRES

Size AWG or MCM	A Not more Than Three Conductors in Raceway or Cable, or Direct Burial				B Single Conductors in Free Air			
	1 Rubber Insulation, Type R, RW, RU, RUW Type RH-RW in Wet Locations Thermoplastic Insulation, Type T, TW		2 Rubber Insulation, Type RH, RHW Type RH-RW in Dry Locations		3 Weatherproof Insulation, Type WP		4 Thermoplastic Insulation, Type TW	
	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum	Copper	Aluminum
14	15	--	15		xx	xx	xx	xx
12	20	15	20	15	xx	xx	xx	xx
10	30	25	30	25	55	45	40	30
8	40	30	45	40	70	55	55	45
6	55	40	65	50	100	80	80	60
4	70	55	85	65	130	100	105	80
3	80	65	100	75	150	115	120	95
2	95	75*	115	90*	175	135	140	110
1	110	85*	130	100*	205	160	165	130
0	125	100*	150	120*	235	185	195	150
00	145	115*	175	135*	275	215	225	175
000	165	130*	200	155*	320	250	260	200
0000	195	155*	230	180*	370	290	300	230
250	215	170	255	205	410	320	340	265
300	240	190	285	230	460	360	375	290
350	260	210	310	250	510	400	420	330
400	280	225	335	270	555	435	455	355
500	320	260	380	310	630	490	515	405
600	355	285	420	340	710	560	575	455
700	385	310	460	375	780	615	630	500
750	400	320	425	385	810	640	655	515

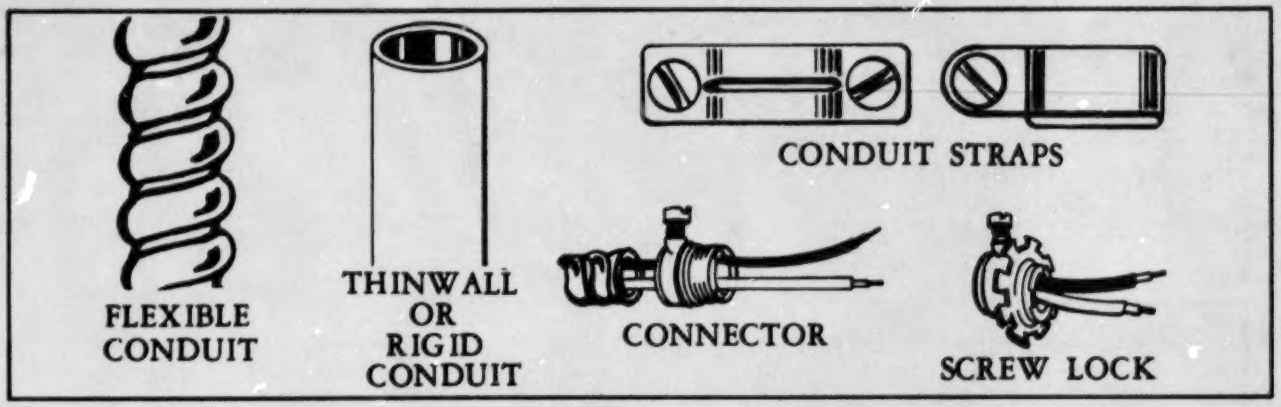
If bare conductors are used with insulated conductors, their allowable current-carrying capacity shall be limited to that permitted for insulated conductors of the same size.

* For three-wire, single-phase service and sub-service circuits, the allowable current-carrying capacity of RH, RH-RW, RHH and RHW aluminum conductors shall be for sizes No. 2-100 amp, No. 1-110 amp, No. 1/0-125 amp, No. 2/0-150 amp, No. 3/0-170 amp and No. 4/0-200 amp.

xx No. 10 is minimum permissible in overhead spans up to 50 ft. in length. For spans over 50 ft. in length, No. 8 is minimum permissible. See NE Code, Section 7314b.

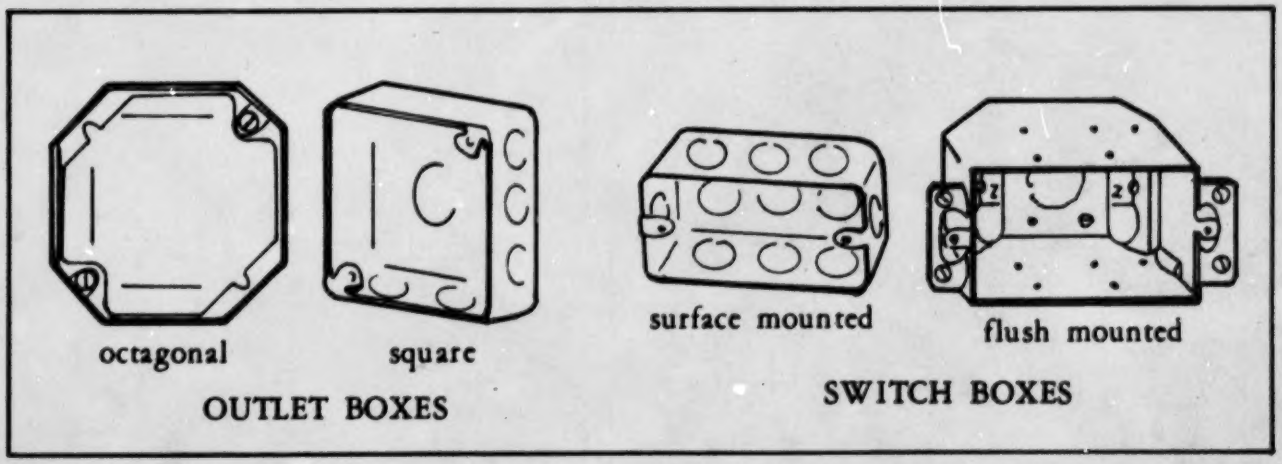
Conduit - Wires requiring mechanical protection necessitate the use of conduit. Other advantages of using conduit are a greater choice of wire colors, the use of additional conductors, and added safety if the conduit is properly grounded.

Conduit is available as flexible or nonflexible. Nonflexible conduit can be rigid or thin wall. Rigid has threaded ends and is thicker than thin wall. Thin wall conduit is most often used for farm and ranch wiring. It is available in 10-foot lengths, is easily bent, and is mounted to steel boxes. Metal straps are used to support and keep it in place, and metal connectors and screw locks are used to fasten it to the boxes.



The thin wall conduit may be cut with a 32-tooth hacksaw. A reamer or file is used to remove the rough edges on the inside of the conduit. Care should be taken not to damage or reduce the size of the internal diameter when bending conduit.

Outlet and Switch Boxes - These are installed at every switch, light, or junction point where wires are attached, with the exception of some outside wiring. Outlet boxes are usually octagonal or square. Switch boxes are made for flush or surface mounting.



Both octagon and square boxes are about the same size and measure four inches in diameter and 1½ inches deep.

Flush mounted switch boxes are used in walls when the wire is concealed. Several types and depths of these boxes are available. The most commonly used box has beveled corners with clamps for nonmetallic cable. The sides are removable in order that more than one box can be ganged together to provide for a series of switches or receptacles at one location.

Surface mounted switch boxes are made to fasten to an exposed surface and are widely used in barns and outbuildings. Their corners are round but do not have clamps for nonmetallic cable. They can be used for conduit or cable wiring; but if nonmetallic cables are used, they should be of the type that has a bare ground wire, which is used to ground the boxes.

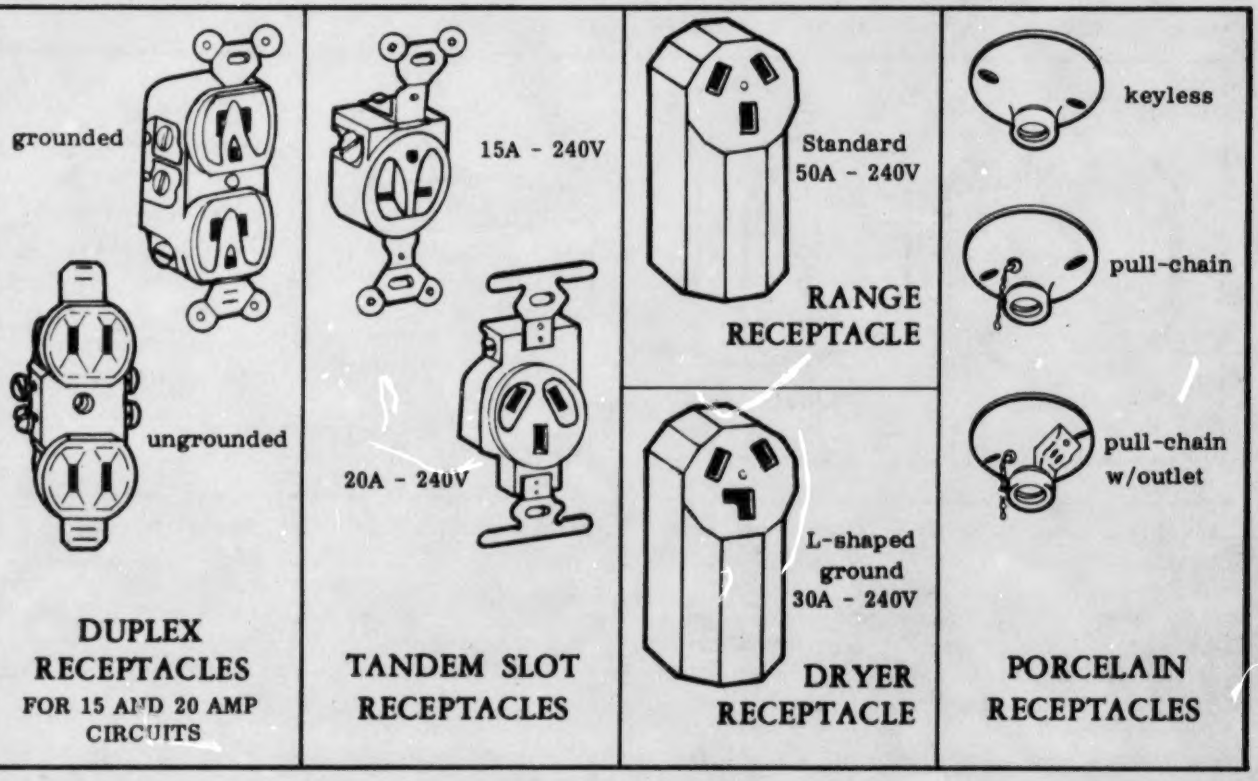
To prevent possible damage to the wires, the number of wires of various sizes that may be permitted in boxes is specified by the National Electrical Code. The following table provides the number allowed for boxes of different sizes:

MAXIMUM NUMBER OF CONDUCTORS PERMITTED IN OUTLET, SWITCH AND JUNCTION BOXES[1]

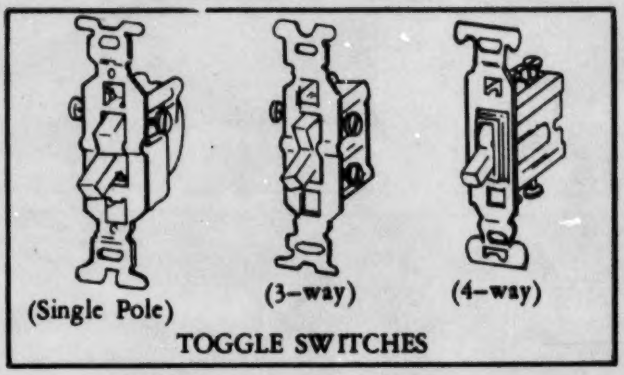
Trade Size of Box	Maximum Number of Conductors			
	No. 14	No. 12	No. 10	No. 8
4" octagon box, 1 1/2" deep	8	7	6	5
4" square box, 1 1/2" deep	11	9	7	5
Switch or handy box, 2" deep	5	4	4	
Switch or handy box, 2 1/2" deep	6	6	5	
Switch or handy box, 3" deep	7	7	6	

[1]These numbers of wires apply if no cable clamps, fixture studs, switches, or receptacles are contained in the box. If the box contains cable clamps or fixture studs, the number of wires shall be reduced by one, with a further reduction of one wire if flush switches or receptacles are contained in the box. Each wire running through the box without splice is counted as one. Each wire terminating in the box is counted as one.

Receptacles - The following are several of the different types of receptacles available:



Switches - Several kinds of switches are available. Three types are the single-pole, three-way, and four-way. These differ in number of terminals and in the number of places from which they can control lights. Single-pole switches have two terminal screws and control lights from one location. Three-way switches have three terminals and control lights from two locations. Four-way switches have four terminals and are used in combination with three-way switches to control lights from three or more locations.

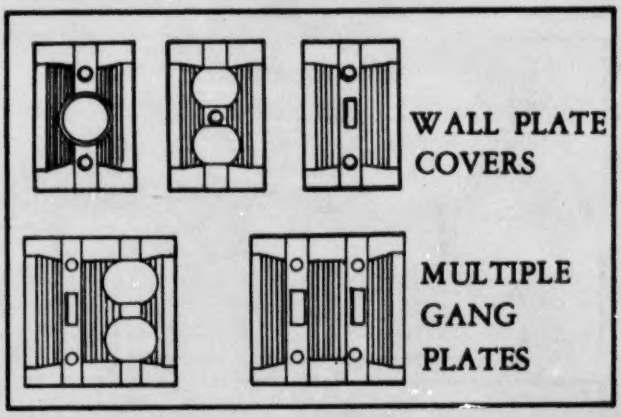


TOGGLE SWITCHES

Blank Covers for Boxes - Blank covers are used to cover surface mounted boxes serving as junction boxes for splices or future receptacle installations.

BLANK COVERS FOR BOXES

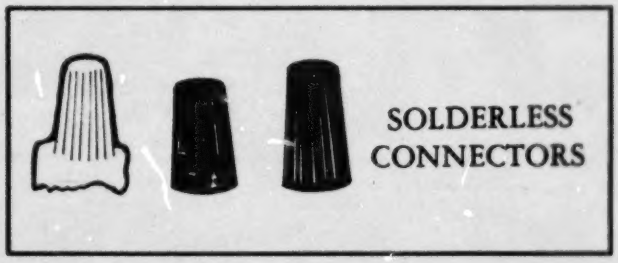
Wall Plates - Switch, receptacle, and combination plates are available in bakelite, metal, glass, and other materials. Several different colors and designs are available.



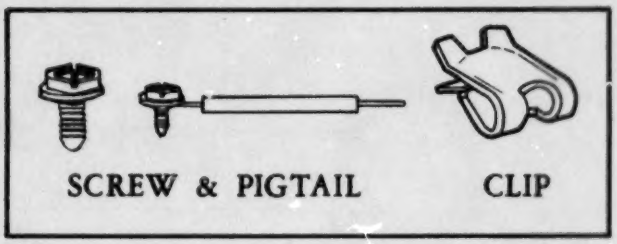
Connectors - Cables are connected to boxes that do not have built-in cable clamps with cable connectors. These are available to fit different sizes of knockouts in boxes.

CABLE CONNECTORS

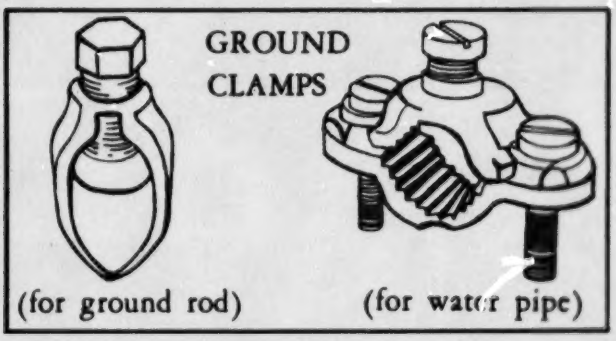
The pressure-type split-bolt connector is used to connect outside wires to entrance wires. When connecting aluminum to copper wires, a spacer should be placed between the two to prevent corrosion.



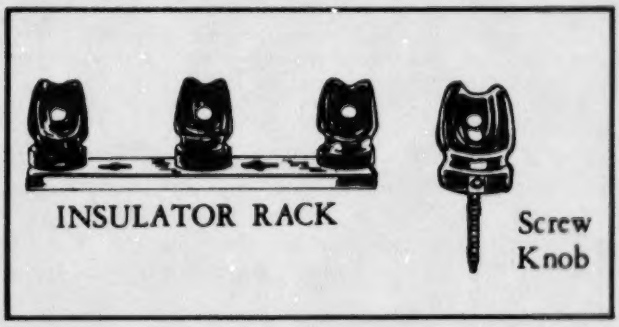
Several kinds of solderless connectors are available. These are used to join wires inside junction boxes. One kind has a coil spring thread inside the cap which is turned onto the pigtail splice to make and insulate it in one operation.



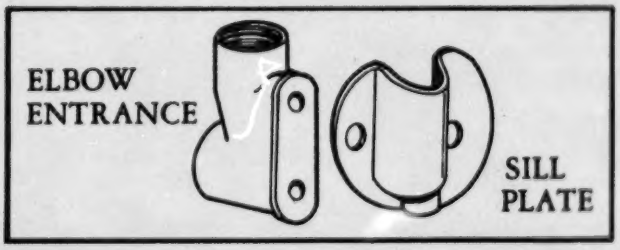
Grounding Screws and Clips - These may be used to ground conductors to boxes. Boxes having tapped holes use the screw and pigtail. If the box does not have tapped holes the grounding clip may be used.



Ground Clamps - Two types of ground clamps are shown here. One is for use with a ground rod and the other for grounding the system to deeply buried water pipes. Ground rods should be at least eight feet long.

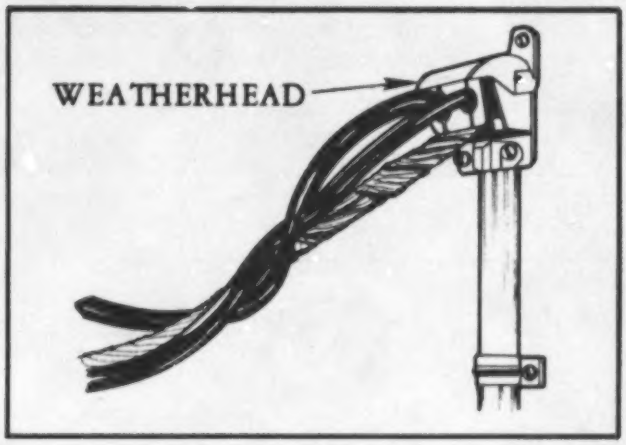


Insulators - Outdoor wires are supported by insulators. Racks are used for long spans and screw knobs are placed in areas having a moderate amount of tension.



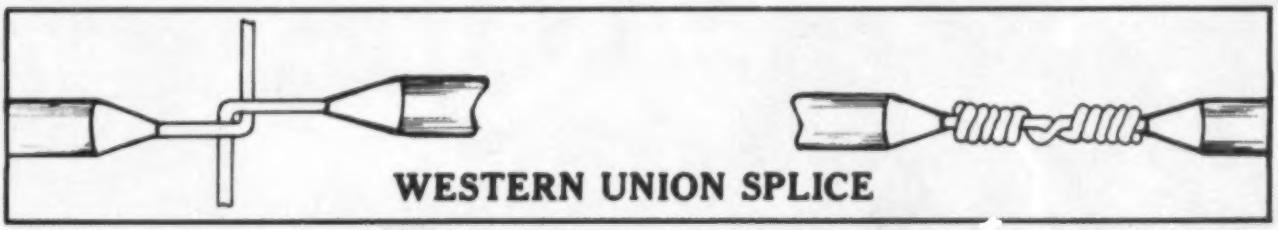
Entrance Elbow or Sill Plate - These may be used where conduit or entrance cable enters the building. A removable cover on the elbow aids in installing the wires. The sill plate fits around the entrance cable where it enters the building.

Entrance Cap or Weatherhead - Several types are available; shown here is the serviceable type. The weatherhead protects the entrance cable connection.

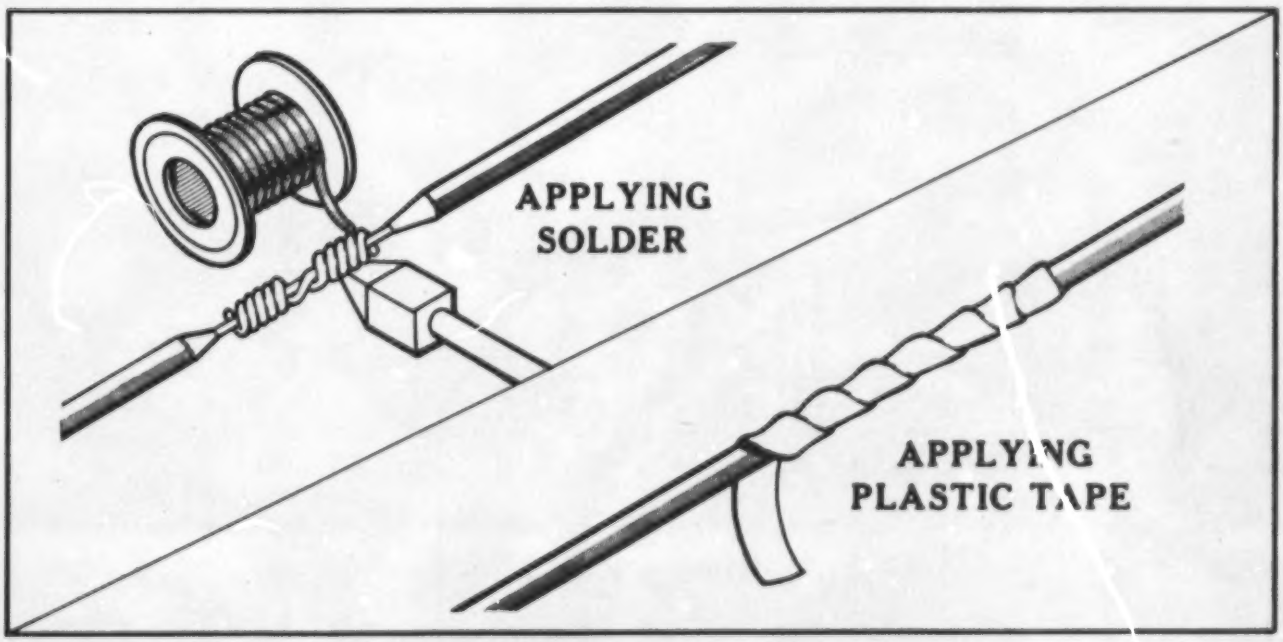


2. COMMON SPLICES AND CONNECTIONS

Western Union - This splice is used when strength is required in the splice, such as running a wire from one building to another. Remove enough insulation from the wires to be spliced to allow 5-6 turns of the wire. If the insulation is removed with a knife, it is cut at a slant to prevent cutting the wire which would reduce its strength. Combination wire cutters and strippers are available and can be adjusted to the correct wire gauge and not damage the wire. To begin the splice, each of the wires is bent into a 90-degree angle about one inch from the insulation. The wires are crossed and one wire is wrapped around the other wire. Pliers can be used to smooth the sharp edges.



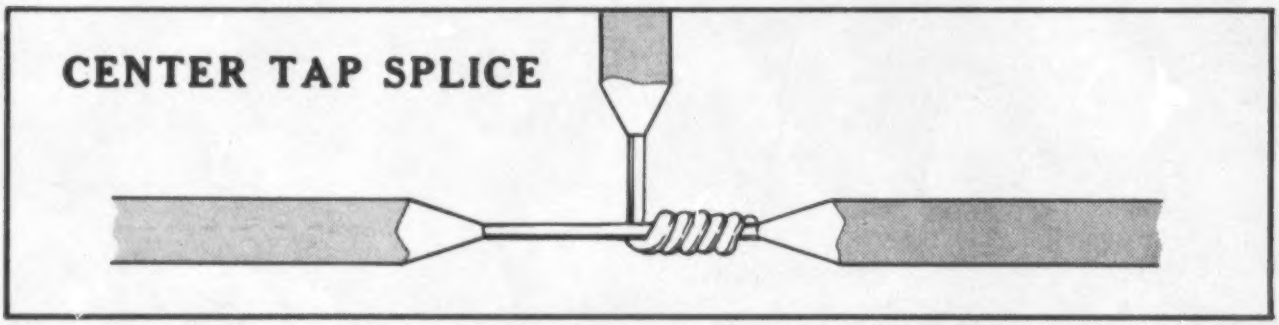
To solder the western union splice, apply rosin core solder by holding the soldering iron to the underside and against the wire until the wire will melt the solder and allow it to flow into every crevice in the splice.



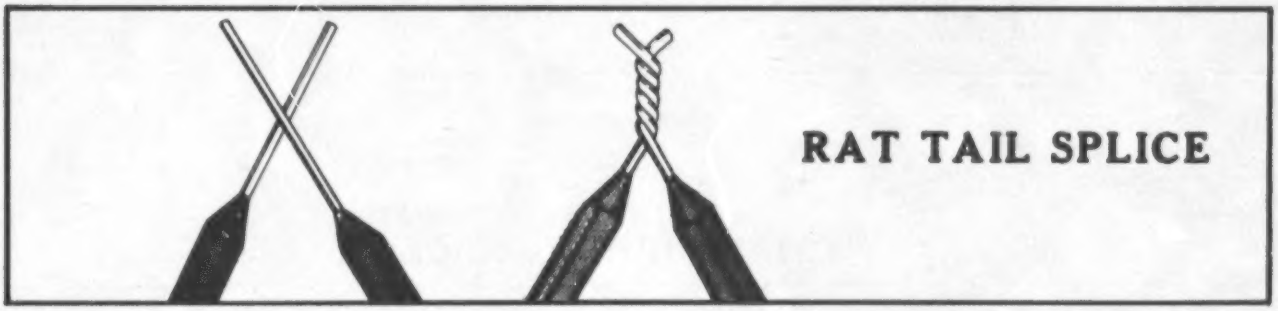
To tape a splice, plastic electrician's tape is extended about 3/4 of an inch over the insulation on one end. Each lap is extended one-half the distance of the previous wrap. The tape is kept tight as each wrap is

made and is wrapped about 3/4 of an inch over the insulation on the opposite end. Two complete wrappings over the splice result in four thicknesses of tape which is sufficient for proper insulation.

Center Tap - The tap splice is used to branch off of a wire and go in another direction. Since this splice has very little strength, the insulation should be used to anchor the tap wire. Remove about 2½ inches of insulation from the main wire. The tap wire is bent into a 90-degree angle about one inch from the insulation. The tap wire is placed around the center of the main wire and 7-8 wraps are made. The splice is then soldered and taped.

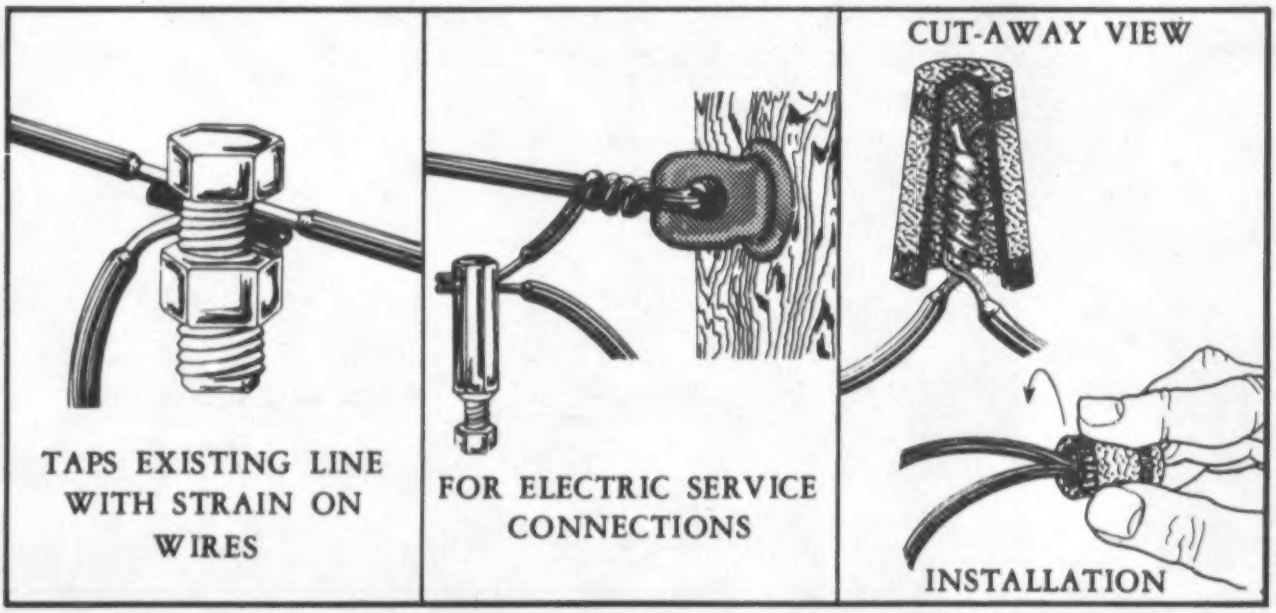


Rat Tail - This splice is used inside junction boxes where the conductors are clamped in the box. This splice has very little strength. It should be soldered and taped or insulated with a solderless connector.

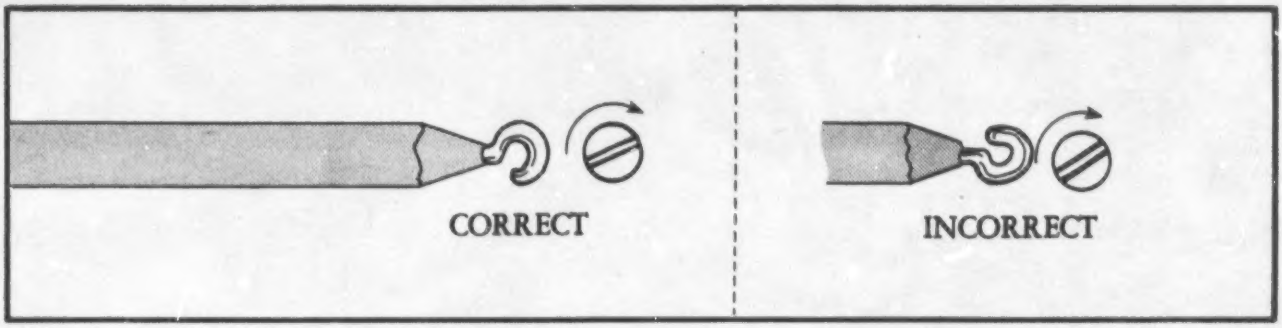


Other Connections - Examples of other necessary connections are shown here:

SOLDERLESS CONNECTORS



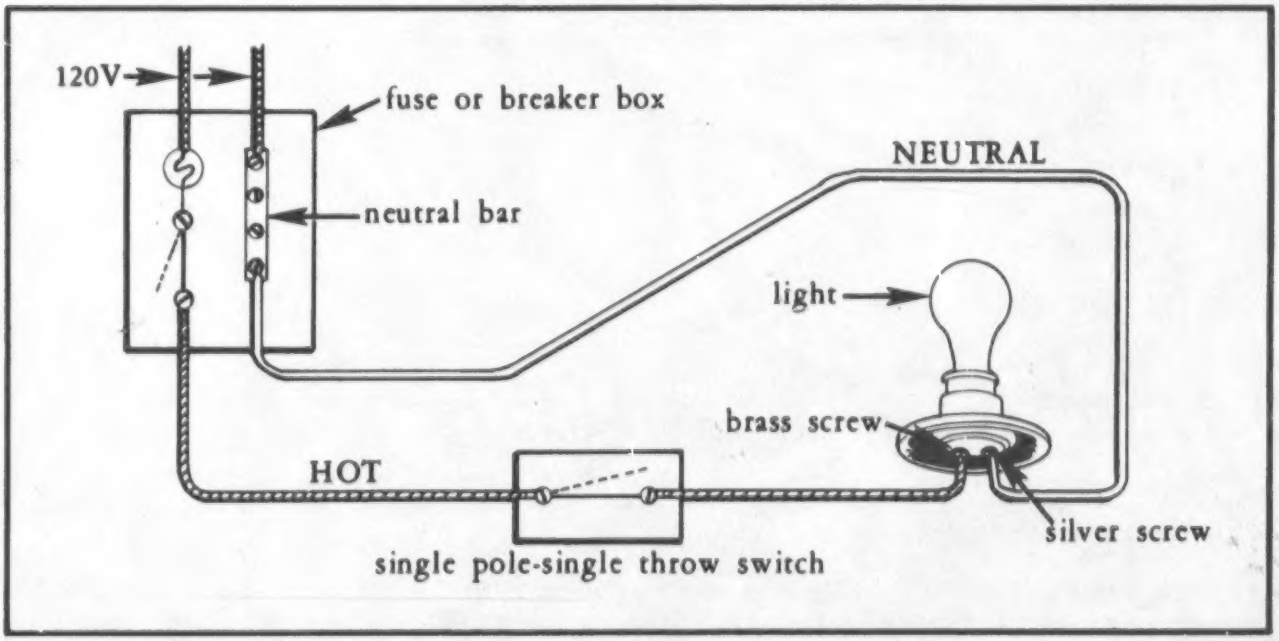
CONNECTIONS MADE AT SCREW TERMINALS



When making connections to screw terminals on switches, outlets, etc., attach the wire loop to the terminal in the direction in which the screw turns to tighten.

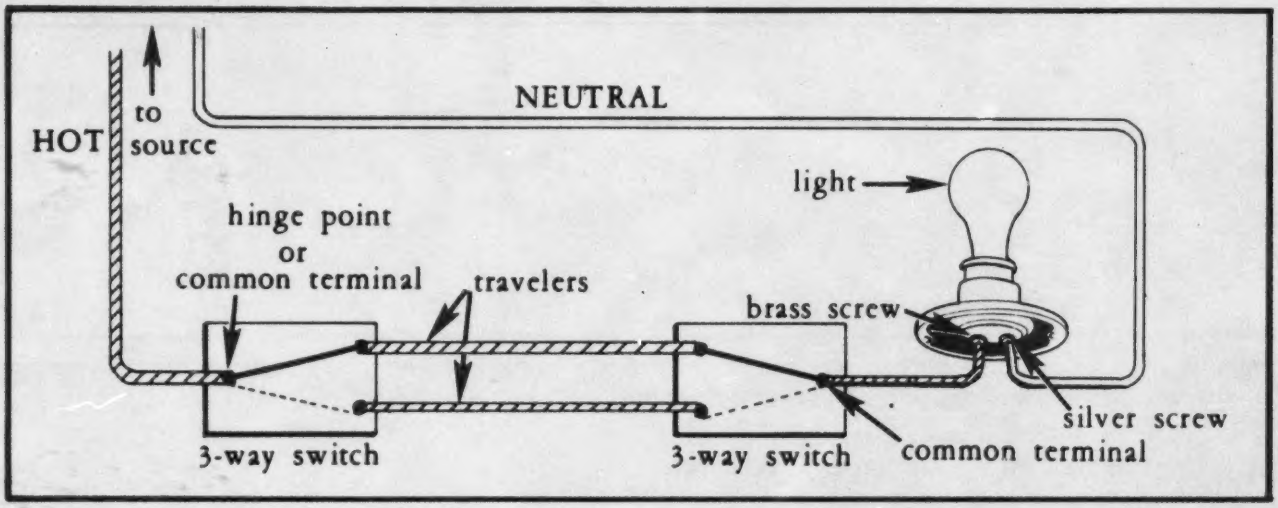
3. TYPES OF SWITCHES AND CIRCUIT DIAGRAMS

Simple Switches - A simple switch (single pole-single throw) controls a circuit from one location. Toggle, mercury, silent, rocker button, and push button are the types available. The thermostat and humidistat are two types of single pole switches operated by mercury. A single pole switch has two terminals (screws) and two positions, open and closed. Switches should never be installed in a neutral line. The following wiring diagram shows a single pole-single throw switch connected in a circuit to control a light. With the switch in the fuse box in the closed position, the flow of current can be traced to the switch, through the switch when switch is closed, through the light, and back to the source on the neutral wire.



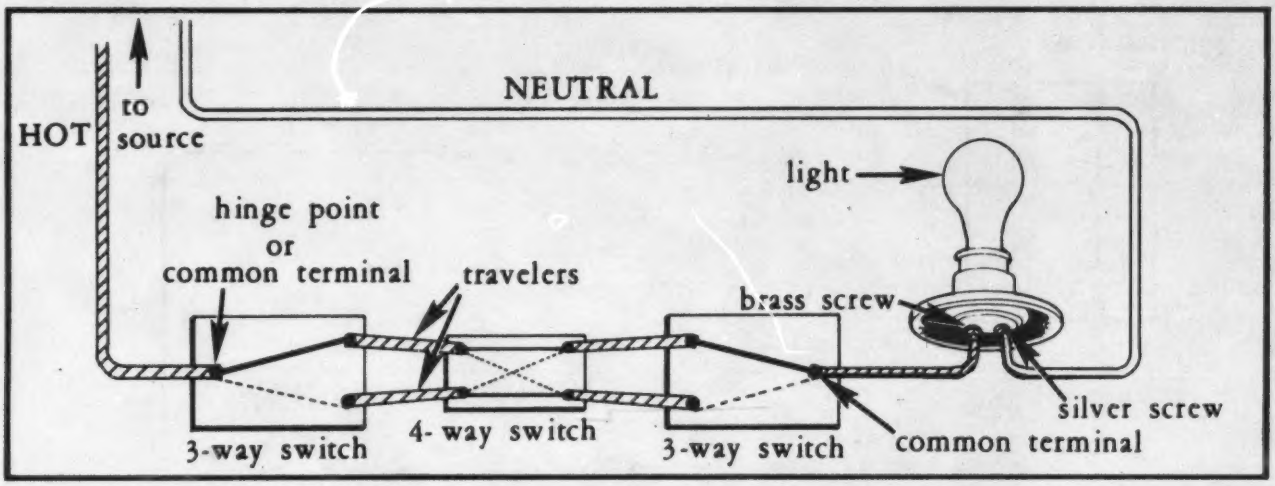
Three-Way Switches - A three-way switch is referred to as a single pole-double throw switch, and is used to control a circuit from two locations. Three-way switches have three terminals (screws). The single terminal on the side of the switch is called the common terminal, while the two terminals on the opposite side are called traveler terminals. To install two three-way switches, the hot wire from the power source is connected to the common terminal of one of the switches. Each of the traveler terminals of one switch is wired to the traveler terminals of the other switch. The common terminal of the remaining switch is connected to the hot lead of the light. The neutral lead on the light is connected to the neutral wire. The porcelain light receptacle has a brass screw for the hot lead and silver screw for the neutral wire.

On the following page are the operating principles and wiring diagram of three-way switches controlling a light. The current flow can be traced from the hot wire through the circuit to show that either switch will turn the light on or off.



Four-Way Switches - Four-way switches are used between three-way switches to provide additional points of control for a circuit. They are wired to the two traveler wires of the three-way switches. Four-way switches have four terminals (screws). The traveler wires between the two three-way switches are cut and attached to the terminals of the four-way switch and are wired to feed straight through or diagonally through the four-way switch.

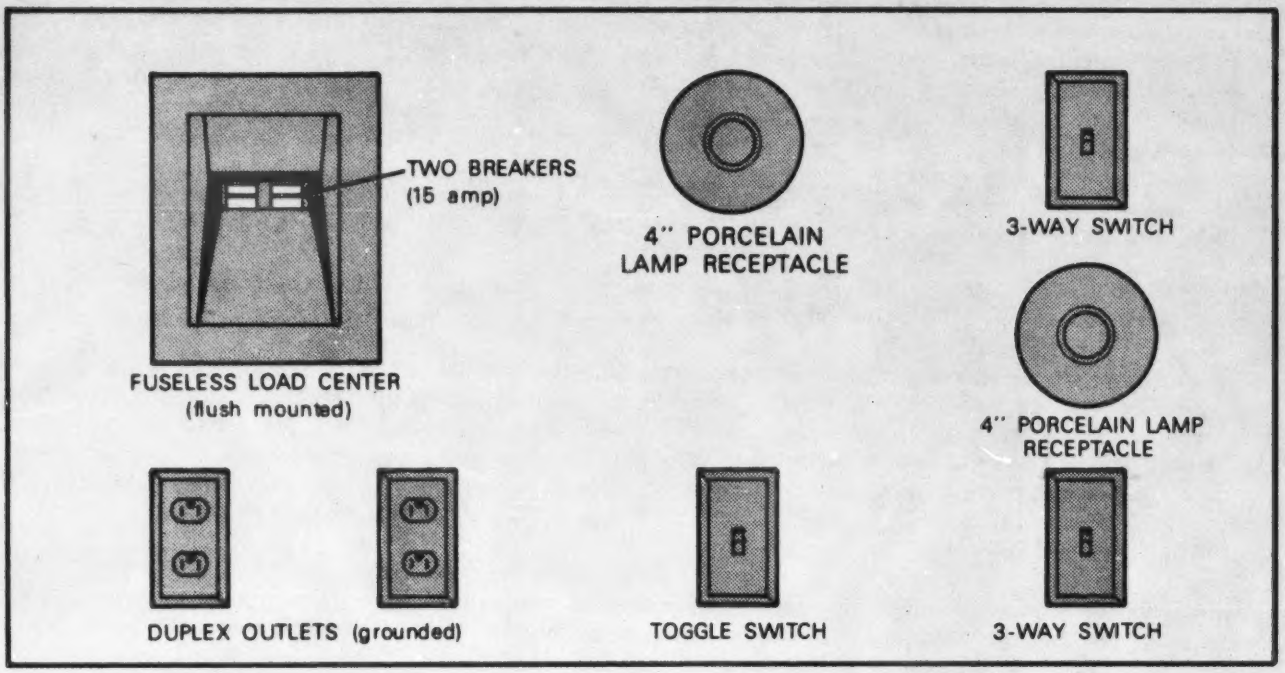
The current flow can be traced in the following circuit diagram from the hot wire source to show that either three-way switch or the four-way switch will turn the light on or off.

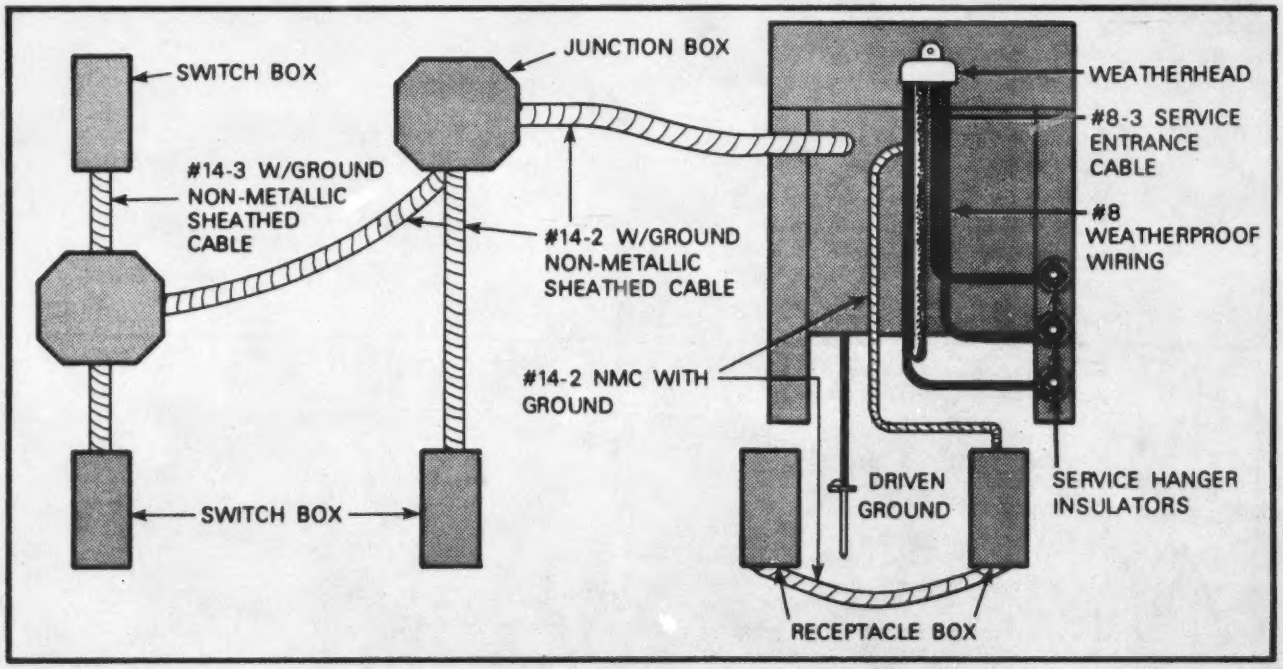


4. INSTALLING LIGHTING AND OUTLET CIRCUITS

The following procedure will make use of an electrical demonstration board found in most vocational agriculture shops. No. 14 wire should be used on the demonstration board for ease in making connections. In actual wiring procedures No. 12 wire is required by the National Electrical Code. No. 14-2 romex with ground should be used for both the outlet and lighting circuit. No. 14 three-wire romex with ground should be used between the three-way switches. Use black plastic tape to mark white wires when used as hot wires. Solderless connectors should be used to make splices. Romex clamps are used to secure cables to boxes.

FRONT AND BACK VIEW OF DEMONSTRATION BOARD





Outlet Circuit - Strip the romex and remove the insulation from the black and white wires, place the romex into the breaker box, and connect the black wire to the breaker terminal. Connect the white and bare wires to the neutral bar. Place the other end of the romex through the first outlet box, strip and remove the proper amount of insulation. Connect the black wire to the brass screw (small slot side of outlet), the white wire to the silver screw (large slot side of outlet), and the bare wire to the safety-ground (green) screw. Use the same color code and connect the first outlet to the second outlet with another length of romex. Install outlets and place covers on the outlet boxes.

Lighting Circuit - Place No. 14-2 romex with ground into the breaker box. Strip the romex and remove the proper amount of insulation. Connect the black wire to the breaker terminal and the white and bare ground wires to the neutral bar. Push the other end of the romex into the first junction box then strip and remove the insulation. Using another length of No. 14-2 romex with ground, place one end into the junction box and the other end into the first switch box. Strip and remove the proper amount of insulation.

Install another No. 14-2 romex with ground from the first junction box to the second junction box for the light to be controlled by 3-way switches. Strip and remove the proper amount of insulation.

Using No. 14-3 romex with ground, run a length from the second junction box to each of the 3-way switch boxes. Strip and remove the proper amount of insulation.

All wire has now been run and connections can be made at this point. In the first junction box, the following splices should be made: (1) Black wire from breaker box to white wire (marked with black tape) from the first switch box and to the black wire going to the second junction box, (2) Black wire from switch box and black lead of the light, (3) White wire from breaker box to white lead of the light and to white wire going to the second junction box, (4) Bare safety ground from the breaker box, switch box, and second junction box should be attached to a grounding clip. Place the porcelain light fixture on the junction box and install the light fixture.

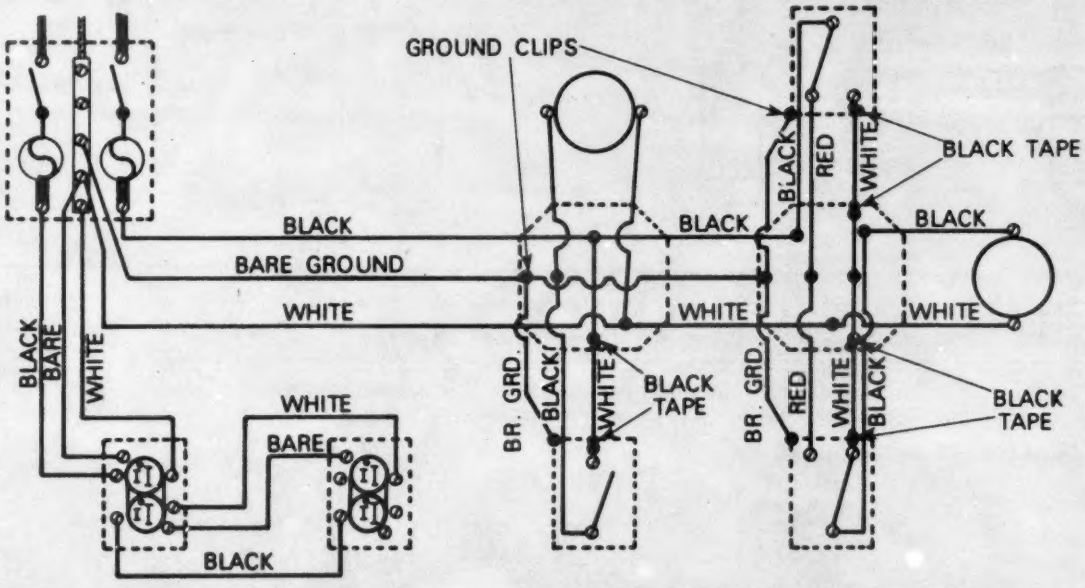
In the first switch box, connect the black wire to one switch terminal and the white wire (marked with black tape) to the other terminal. Attach the bare safety ground to the switch box using a grounding clip. Using grounding clips, attach the bare ground wire to each switch box.

In the three-way switch boxes, connect the black wire to the common terminal and the red and white wires to the traveler terminals of the three-way switches. The white wires should be marked with black tape. Using grounding clips, attach the bare ground wire to each switch box.

In the second junction box, make the following splices: (1) Black wire from the first junction box and black wire from one three-way switch. (2) Black lead of light and black wire from the second three-way switch. (3) Red traveler wires. (4) White traveler wires (marked with black tape). (5) White wire from the first junction box and white lead of the light. (6) Bare ground wire from the first junction box and from each three-way switch should be attached to a ground clip.

Mount the porcelain light fixture on the junction box and install three-way switches and cover plates.

WIRING DIAGRAM FOR OUTLET AND LIGHTING CIRCUITS



Energize the fuse box and check the circuits and switches to determine if they function properly. Care should be taken to be sure the circuit is polarized when energized. Polarizing the circuit means that the neutral wire from the power source is connected to the neutral wire of the demonstration board.

5. PLANNING THE FARM WIRING SYSTEM

The farm wiring system includes both exterior and interior wiring, and extends from the point of supply to various outlets located inside and outside of farm buildings. A well-planned wiring system can pay the farmer dividends by reducing the size of wire, size of electrical equipment needed, amount of wire used, installation labor, and the amount of electricity used.

A suggested procedure for planning a farm wiring system is as follows:

(1) Prepare a farmstead plan with building and layout plans to scale. Include the present power source and locate the meter in the most efficient location.

(2) Determine the number of circuits needed in each building and locate the outlets. The following suggestions apply to a farm residence.

a. The number of general purpose outlets needed is determined by taking the floor plan and spacing at least one outlet for every 12 feet of wall space. This spacing provides a circuit for any appliance having an extension cord six feet long. A maximum of eight convenience or lighting outlets should be on any one circuit (less in kitchen area). The number and size of light fixtures is determined by the amount of floor space in a given area and the candle power of the fixtures. At least two general purpose circuits should be provided in the kitchen area to accommodate high-wattage appliances. Number 12 wire is used for general purpose circuits and should be protected with 15 or 20 ampere fuses, circuit breakers, or ground fault circuit interrupters.

b. Special purpose circuits are needed for appliances such as the range, water heater, air conditioner(s), food freezer, water system, and clothes dryer. The wire size and circuit protection is based on safe ampere capacity and permissible voltage drop. Graphical electrical symbols should be placed on building floor plans to indicate outlets. Examples are as follows:

ELECTRICAL SYMBOLS

GENERAL OUTLETS

- Lighting Outlet
- Ceiling Lighting Outlet for Recessed Fixture (Outline Shows Shape of Fixture.)
- L — Lighting Outlet with Lamp Holder
- L PS — Lighting Outlet with Lamp Holder and Pull Switch
- F — Fan Outlet
- J — Junction Box
- D — Drop-Cord Equipped Outlet
- C — Clock Outlet

To Indicate Wall Installation of Above Outlets, Place Circle Near Wall and Connect with Line as Shown for Clock Outlet.

SWITCH OUTLETS

- S — Single-Pole Switch
- S_2 — Double-Pole Switch
- S_3 — Three-Way Switch
- S_4 — Four-Way Switch
- S_{WP} — Weatherproof Switch
- S_D — Automatic Door Switch
- S_P — Switch and Pilot Light

CONVENIENCE OUTLETS

Duplex Convenience Outlet (Grounding Type Outlet Required)

Triplex Convenience Outlet (Substitute Other Numbers for Other Variations in Number of Plug Positions, Such as 1 for Single Convenience Outlet)

Duplex Convenience Outlet-Split Wired

Weatherproof Convenience Outlet

Combination Switch and Convenience Outlet

Floor Outlet

Range Outlet

Special-Purpose Outlet. Use Subscript Letters to Indicate Function. DW-Dishwasher, CD-Clothes Dryer, etc.

c. Service entrance and distribution panel requirements can be determined from plans and by consulting with the power supplier. Service entrance cables and service equipment are capacity rated and should have a rating that is adequate to handle the electrical load safely. A modern farm home may require equipment with a capacity to handle as much as 200 amperes. A distribution panel with 23-25 branch circuit positions is recommended for the home. Some of the branch circuit positions that may be required in a residence are as follows:

Branch Circuit Position	Number
Electric Range (240V)	2
Clothes Dryer (120/240V)	2
Water Heater (240V)	2
Automatic Washer (120V)	1
Freezer (120V)	1
Appliance Circuits (120V)	3
Water Pump (120V or 240V)	1 or 2
Lighting Circuits (120V)	4
Fuel-Fired Heating System (120V)	1
Dishwasher (120V)	1
Waste Disposer (120V)	1
Air Conditioner (240V)	2
Spares	2 or 3
	23 or 25

SUGGESTED STUDENT ACTIVITIES

I. True or False

_____ 1. The National Electrical Code insures safety but planning is important to provide an adequate and efficient wiring system.
_____ 2. The smaller the wire size, the more the resistance, and the greater the voltage drop.
_____ 3. The smaller the gauge number, the larger the wire size.
_____ 4. Aluminum and copper wire of the same gauge are rated equal in ampere carrying capacity.
_____ 5. Stranded wire is more flexible than solid wire.
_____ 6. USE refers to underground service entrance wire.
_____ 7. Type RHW can be used for service entrance.
_____ 8. Number 10 Type TW copper wire is rated at 55 amperes and is adequate for a welder circuit.

_____ 9. Conduit may be flexible or nonflexible and provides mechanical protection for wires.

_____ 10. Outlet boxes are sometimes referred to as junction boxes and may be square or octagonal.

_____ 11. All interior connections should be made inside an outlet box.

_____ 12. When using No. 12 wire, no more than 4 conductors can be in a 2 inch switch box.

_____ 13. Single pole-single throw switches have three screw terminals.

_____ 14. If copper and aluminum wires are connected, oxidation and corrosion may occur.

_____ 15. The western union splice is not as strong as the center tap splice.

_____ 16. Switches should be installed in the neutral wire.

II. Discussion Questions

1. Name and discuss 10 wiring materials.

2. Name and discuss several branch circuit positions to be planned for in the distribution panel. Explain why spares are necessary.

3. Explain the correct procedure for attaching a wire to a screw terminal.

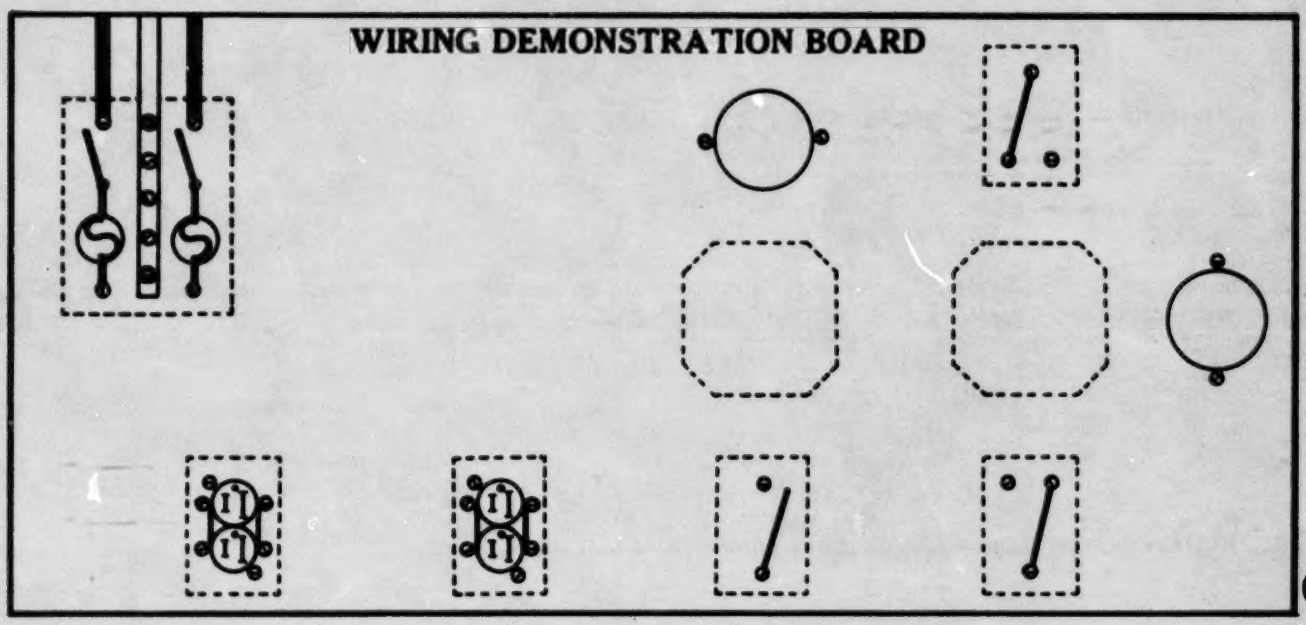
4. Name several considerations to make in planning the farm wiring system.

III. Diagram the following operating principles:

1. A light controlled by a single pole-single throw switch.

2. A light controlled from three locations.

IV. Complete the wiring diagram for the demonstration board.



V. Draw the electrical symbol for each of the following:

1. lighting outlet
2. special purpose outlet
3. floor outlet
4. three-way switch
5. duplex convenience outlet

VI. Skills to be performed by the student:

1. Splicing, soldering, and taping
2. Identification of wiring materials
3. Wiring a demonstration board
4. Wiring a farm structure

ALL RIGHTS RESERVED

Reproduction prohibited without written permission.
Vocational Instructional Services
Texas A&M University
College Station, Texas 77843

TX 80 13308

V. A. III
V-A-4
V-A-5

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
This document has been reproduced as received from the person or organization originating it.
Minor changes have been made to improve reproduction quality.
Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

STUDENT MATERIALS

ELECTRIC MOTORS

"PERMISSION TO REPRODUCE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY

J Page

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

1. ADVANTAGES OF USING ELECTRIC MOTORS

The use of electric power in agricultural production and processing is steadily increasing. Electric motors compared with other kinds of power units have many advantages. They are as follows:

a. Economical to operate. A 1/4 Hp electric motor can do physical work equal to approximately 2 1/2 men, and the motor can work continuously.

b. Dependable. Electric motors are always ready to work. Temperature extremes and changes have little effect on motor starting or operation.

c. Efficient. Compared to other power sources, the electric motor is one of the most efficient. The efficiency of electric motors varies from 65 to 95 percent, depending on the motor type and conditions under which it operates.

d. Long life. Smooth operation and few moving parts with little to wear out enables an electric motor to last 20-30 years with proper care.

e. Simple to operate. No special skills or experience are required to operate electric motors. They can be started and stopped by a simple switch.

f. Safe. Electric motors are safe if properly installed. They require no inflammable fuel and produce no dangerous flames or fumes. There are no open gears and no physical labor is required to start an electric motor.

g. Minimum servicing. Electric motors require a minimum of attention. There is no fuel to carry, no oil to change, no battery to charge or service, and nothing to freeze.

h. Quiet operation. When properly applied and installed operate quietly and smoothly with very little vibration.

i. Compact and automatically controlled. Electric motors require little space for mounting and use with other equipment. The fact that they can be automatically and remotely controlled greatly increases their adaptability as a source of power.

j. Adaptable. Electric motors are light and can be easily moved. They are adaptable to different operating positions and conditions.

2. CALCULATING COST OF OPERATION

The actual wattage of electric motors will be less than the relationship volts X amps = watts. The true relationship is volts X amps X power factor = watts. In estimating power consumption of motor sizes up to 1 Hp, figure 1200 watts per horsepower; for motor sizes 1 Hp and larger, 1000 watts per horsepower may be used. Larger three-phase motors should be estimated at 800 watts per horsepower.

An example of cost calculation is as follows:

a. Figure the cost of pumping 2000 gallons of water with a 1/4 Hp motor if it pumps 500 gallons per hour.

b. $\frac{\text{2000 gallons}}{\text{500 gallons/hour}}$ = 4 hours operating time

c. 1/4 HP = approximately 300 watts

d. $\frac{\text{300 watts X 4 hours}}{\text{1000 watts/KW}}$ = 1.2 kilowatt hours used

e. 1.2 KWH X 5¢/KWH = 6¢ cost for pumping 2000 gallons of water

3. FACTORS TO CONSIDER IN SELECTING ELECTRIC MOTORS

The selection of electric motors for farm use should take into consideration the type of electric power available (voltage and phase), type and size of load, and conditions under which the motor must operate. A motor must do three things: start the equipment load, drive the load once it is started, and survive the abuse of the surroundings in which it must operate.

Type of power available - The type of electric service available is important because a 230 volt motor should not be selected if only 115 volt circuits are available. Also, a three-phase motor cannot be operated on an electrical system having only single-phase service.

Size of motor - The size of electric motors is rated in horsepower. The rating given to a motor refers to the power that it will develop when the motor is turning at full speed. The "rules of thumb" used for estimating the size of motor needed are: (1) if the equipment can be operated by hand, a 1/4 Hp motor will usually be adequate, and (2) if a gasoline engine is to be replaced by an electric motor, an electric motor approximately 2/3 the Hp rating of the engine will usually be adequate.

Starting load - The motor selected must have the starting torque or turning force to start the load. Motors have different methods of starting and starting torques. Types of motors used on farms and in homes are as follows: (1) split phase, (2) capactor start - induction run, (3) capacitor start - capacitor run, (4) repulsion start - induction run, (5) series or universal, (6) shaded pole, and (7) three-phase.

Speed requirement - Electric motors are rated at the speed the shaft will turn in revolutions per minute (rpm) when the motor is operating at full speed. The rpm of the motor should be the speed needed to operate the equipment at the proper speed.

Bearing type - Electric motors may have sleeve bearings or ball bearings. Motors with ball bearings will normally require less maintenance and can be mounted in any position.

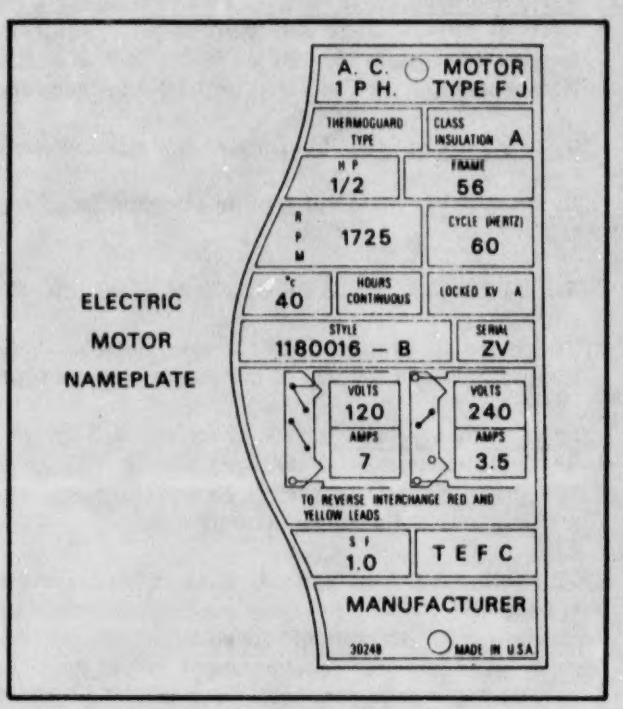
Base type - The motor may need a rigid base, a sliding adjustable base, or a cushion mount to reduce vibration and wear. The type of base is determined by application of the motor.

Environment - The type of motor enclosure (frame) should be selected to provide proper protection to the motor from its surroundings - primarily protection from dust, dirt, and water. The four most common type enclosures for farm motors are: (1) open drip proof, (2) splash proof, (3) totally enclosed - fan cooled, and (4) explosion proof.

4. ELECTRIC MOTOR NAMEPLATE INFORMATION

The nameplate on an electric motor provides information that will assist a person in selecting the proper motor for the job, in making installation, and in energizing the motor with the proper voltage.

The following illustration gives an example of the information found on a motor nameplate and can be referred to as the motor's "pedigree".



A. C. - 1 PH. - This indicates that the motor will operate on alternating current and single - phase power.

Motor Type - This refers to the model or motor type as designated by the manufacturer. Type FJ is the code used by Westinghouse to designate a capacitor start motor.

Thermoguard Type - This indicates that the motor has a built-in thermal device to protect it from too many amperes. The thermal relay opens the circuit when the ampere flow becomes high enough to endanger the motor windings. The thermal relay may close automatically after it cools, or it may be the manual-reset type requiring an operator to push the reset button each time the thermal relay opens.

Class Insulation - "A" indicates that the motor is provided with class "A" insulation and that it will withstand a temperature of 105 degrees centigrade or 221 degrees fahrenheit.

HP - 1/2 - This indicates that the motor is designed to pull a 1/2 Hp load when operated at the rated voltage and cycle.

Frame - 56 is a designation giving standard motor dimensions (NEMA Standards). This is very useful information when buying replacement motors. Two-digit frame numbers are divided by 16 to give the distance in inches from the center line of the shaft to the foot of the base. (example: $\frac{56}{16}$ = 3.5 inches)

RPM - 1725 indicates that this motor turns 1725 revolutions per minute when pulling its rated load.

Cycle (Hertz) - 60 cycles per second is the frequency of the power supply for which the motor is designed to operate. (Frequency affects motor speeds.)

40 Degrees Centigrade - When operating under rated conditions this motor will have a 40 degree C (72 degree F) temperature rise above room temperature. Some motors are rated at a 50 degree C rise.

Hours - Continuous - Sometimes referred to as duty. Continuous means that this motor will pull its rated load under rated conditions continuously and not overheat. Some motors are designated as intermittent duty and may be rated for 5, 15, 30, or 60 minute operating times and then allowed to cool before restarting.

Locked KVA - A nameplate designation of locked-rotor KVA (Kilo - Volt - Amperes) per horsepower, measured at full voltage and rated frequency. The higher the locked-rotor KVA, the higher will be the current surge.

Serial Number - Indicates month and year of fabrication; Z is month and V is year.

Volts 120/240 - This is a dual-voltage motor and will operate on 120 volts or 240 volts; however, the windings must be connected properly for the selected voltage. Terminal connections for the two voltages are shown on the nameplate. Note that the motor will draw twice as many amperes when connected for 120 volts as it does when connected for 240 volts.

Service Factor (S.F.) - This refers to the amount of overload that the motor can tolerate on a continuous basis at rated voltage and frequency. A 1.0 service factor indicates no overload tolerated for extended periods of time. A 1.25 service factor indicates that the motor can be overloaded 25% for an extended period of time when operated at rated voltage and frequency.

Type of Housing - This indicates the motor enclosure type. (TEFC - totally enclosed fan cooled.)

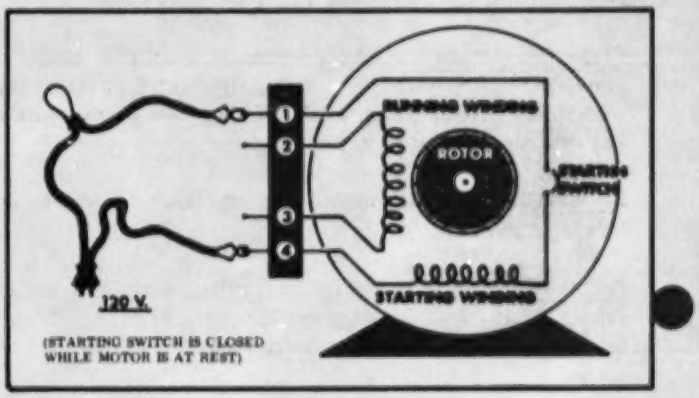
Manufacturer - The name plate information also gives the name and address of the motor manufacturer.

5. TYPES AND USES OF COMMON ELECTRIC MOTORS

There are several types of electric motors. The motor selected will depend upon how it is to be used. Information about several of the electric motor types is as follows:

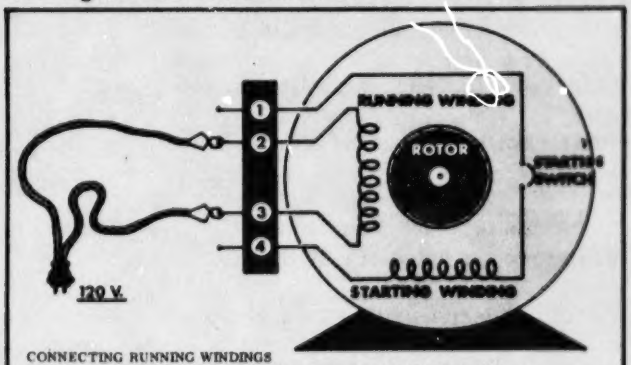
Split - Phase Motor - This motor is used for easy starting loads such as jet pumps, bench grinders, laundry equipment, and machinery tools. The split-phase motor has a high starting current requirement and will draw 6-8 times its normal running current when starting. Sizes available range from 1/20 Hp to 3/4 Hp and are primarily single voltage motors.

The following illustrations show a single-voltage, split-phase motor. Note the starting switch is in the starting winding and is closed when the motor is at rest. As the motor reaches about 80% of its running speed, the starting switch opens and stops the flow of current through the starting winding.



(STARTING SWITCH IS CLOSED WHILE MOTOR IS AT REST)

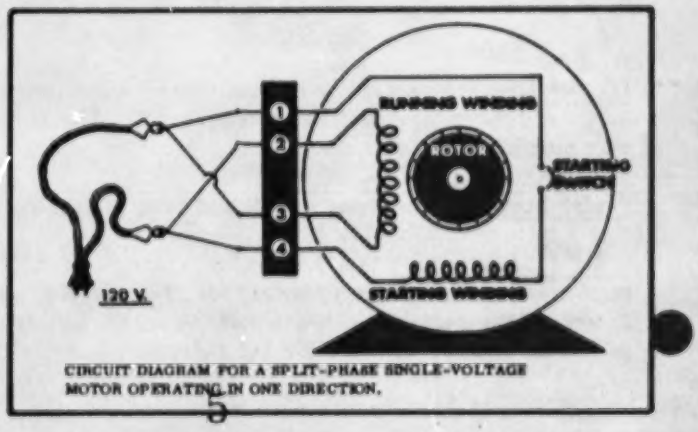
Using a test lamp, continuity can be determined in each of the windings. Test starting windings as shown. The running winding can be tested by attaching the test leads to #2 and #3.



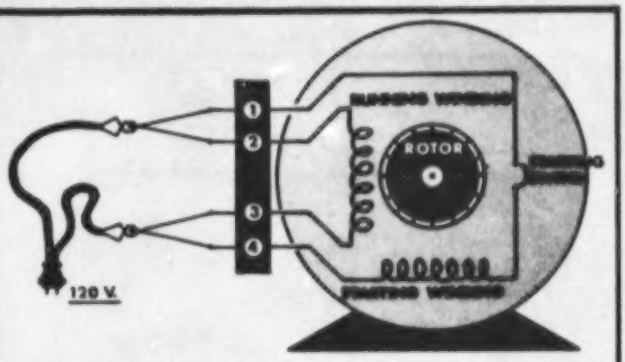
CONNECTING RUNNING WINDINGS TO POWER LEADS ON A SPLIT-PHASE SINGLE-VOLTAGE MOTOR.

When power leads are connected to the ends of the running winding, the motor will hum. The shaft can be turned either direction by hand and the motor will run. When the power leads are connected to the ends of the starting winding, the motor will start and stop as the centrifugal mechanism closes and opens the starting switch.

To operate the motor, one end of the starting and running windings are placed together for one lead and the other ends of both windings are placed together for the other lead.



CIRCUIT DIAGRAM FOR A SPLIT-PHASE SINGLE-VOLTAGE MOTOR OPERATING IN ONE DIRECTION.

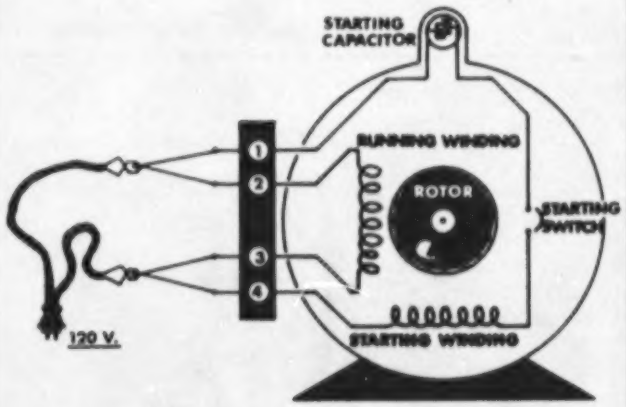


Circuit diagram for a split-phase single-voltage motor operating in opposite direction.

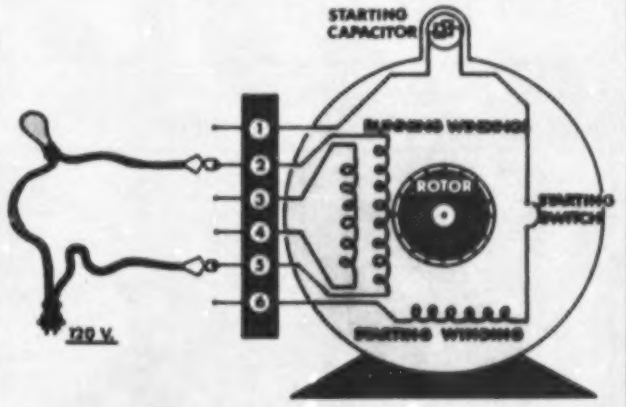
To reverse the rotation of the shaft, the ends of the starting windings are changed with respect to the running winding leads.

Capacitor - Start Motor - This motor is used for difficult starting loads such as air compressors, pumps, blowers, feed grinders, conveyors, and power tools. As the name indicates, this motor has a capacitor in the starting winding to give the motor more starting torque. The capacitor-start motor has a medium starting current requirement and will draw 3 to 6 times its normal running current when starting. When approximately 75% of full load speed has been reached, a centrifugal relay opens a set of switch contacts in the start-winding circuit, thereby removing the capacitor and starting winding from the operating or running circuit.

The capacitor-start motor is constant speed ranging from 900 to 3600 rpm. Sizes available range from 1/8 to 10 Hp. The motor may be obtained as a single or dual voltage motor. Single voltage motors have a starting winding and a running winding. Dual voltage motors have a starting winding and two running windings.



CIRCUIT DIAGRAM FOR A CAPACITOR-START SINGLE-VOLTAGE MOTOR.



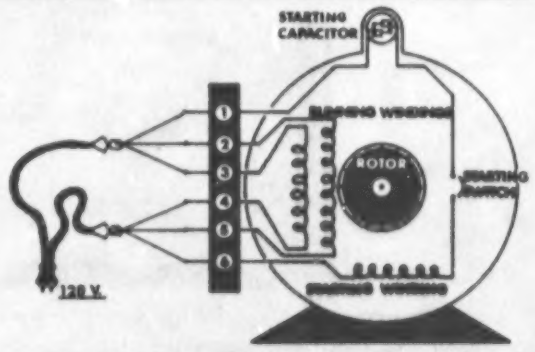
TESTING STARTING WINDING AND RUNNING WINDINGS ON DUAL-VOLTAGE CAPACITOR-START MOTOR, TEST BETWEEN 1 & 6, 2 & 5, AND 3 & 4.

The windings on a capacitor-start, dual-voltage motor may be identified with a continuity test lamp as shown here.

To identify the starting winding, remove the capacitor cover and use the continuity test lamp to check between leads one or six and the capacitor terminals.

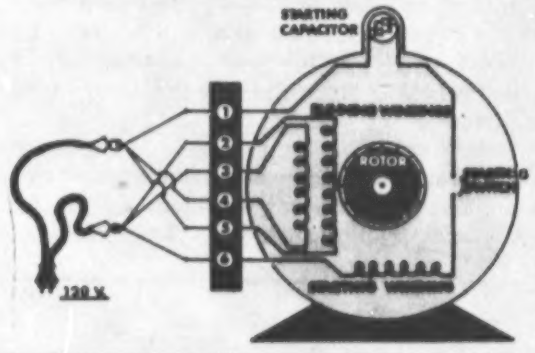
The following illustration shows the wiring diagram for a capacitor-start, dual-voltage motor when operating on 120 volts. The running windings are wired in parallel.

CIRCUIT DIAGRAM FOR DUAL-VOLTAGE CAPACITOR-START MOTOR WIRED TO OPERATE ON 120 V. IN ONE DIRECTION.

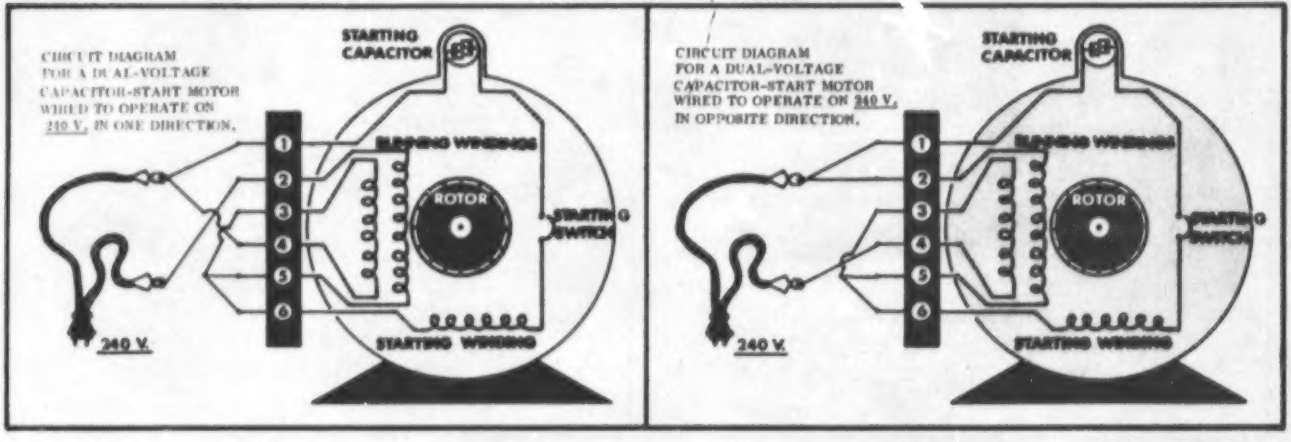


The following illustration shows the wiring diagram for a capacitor-start, dual-voltage motor running in the opposite direction and operating on 120 volts.

CIRCUIT DIAGRAM FOR DUAL-VOLTAGE CAPACITOR-START MOTOR WIRED TO OPERATE ON 120 V. IN THE OPPOSITE DIRECTION.



The wiring diagrams for a capacitor-start, dual voltage motor, when operating on 240 volts, are shown in the following illustrations. The running windings are wired in series.

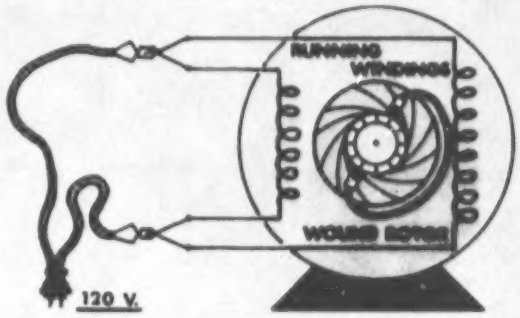

CIRCUIT DIAGRAM FOR A DUAL-VOLTAGE CAPACITOR-START MOTOR WIRED TO OPERATE ON 240 V. IN ONE DIRECTION.
STARTING CAPACITOR
ROTOR
240 V.
CIRCUIT DIAGRAM FOR A DUAL-VOLTAGE CAPACITOR-START MOTOR WIRED TO OPERATE ON 240 V. IN OPPOSITE DIRECTION.
STARTING CAPACITOR
ROTOR
240 V.

Repulsion - Start Motor - This motor is used for heavy starting loads. A high starting torque is provided by a wound rotor and brushes. The many applications include: feed mills, large blowers, silo unloaders, elevators, compressors, and deep well pumps.

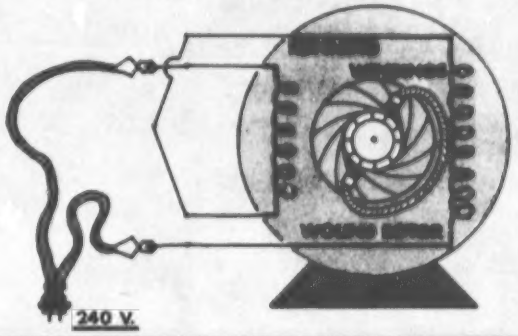
The repulsion - start motor has high starting torque with a low starting current (2 to 4 times the full load current). It is considered a constant speed motor, 1200 or 1800 rpm. The sizes normally available range from 1/6 to 10 Hp and are usually dual voltage. Direction of rotation may be changed by moving the brush ring.

The wiring diagrams for operating on 120 volts and 240 volts are illustrated here. For 240-volt operation, the windings are wired in series, while the windings on 120-volt operation are wired in parallel.

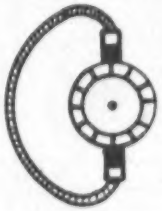
CIRCUIT DIAGRAM
DUAL-VOLTAGE REPULSION-START MOTOR
WIRED FOR 120V OPERATION



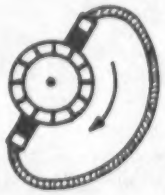
CIRCUIT DIAGRAM
DUAL-VOLTAGE REPULSION-START MOTOR
WIRED FOR 240V OPERATION



SETTING BRUSH RING ON REPULSION-START MOTOR TO DETERMINE DIRECTION OF ROTATION



(DEAD CENTER)
Motor will not start



(CLOCKWISE DIRECTION)

(COUNTER CLOCKWISE DIRECTION)

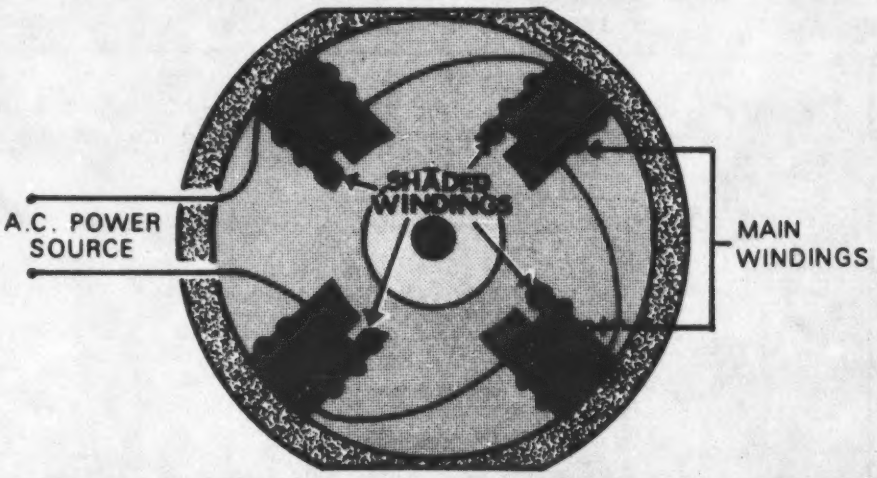
Universal or Series Motor - This motor is a special purpose motor, and usually is made as a part of portable appliances or tools such as drills, grinders, sanders, vacuum cleaners, food mixers, and sewing machines. It can be operated on alternating current (AC) or direct current (DC).

The universal or series motor is designed for intermittent use, is variable speed, and may be reversible. It has a high starting torque and a high starting current. The size ranges from 1/150 to 2 Hp.

SERIES CONNECTION
OF A
UNIVERSAL MOTOR

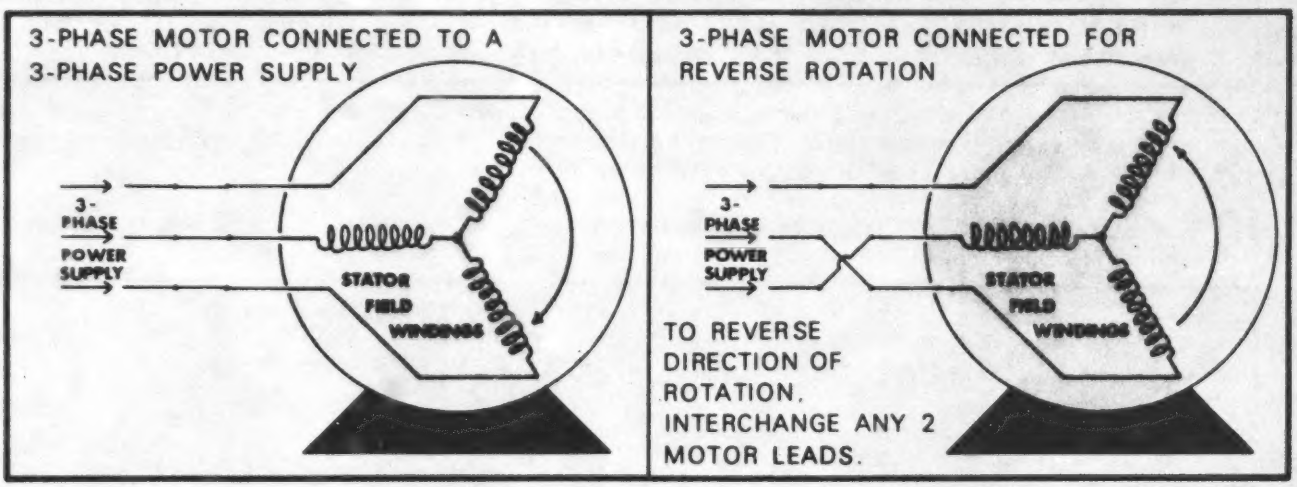
Shaded - Pole Motor - This is a small, single-phase motor that operates on alternating current. It has a low starting torque and low efficiency. Sizes range from 1/20 to 1/6 Hp and it is generally not reversible. This motor is simply constructed and is used for light duty such as small fans, blowers, hair dryers, humidifiers, and timing devices.

FOUR-POLE, SHADED-POLE MOTOR SHOWING MAIN & SHADED WINDINGS



Three - Phase Motor - This motor is of simple construction and is operated only on three-phase alternating current. It has a medium to high starting torque and can be obtained with the designation of low, normal, or high starting current requirement. It is designed for self starting and requires no starting mechanism. The three-phase motor is constant speed and may be obtained in sizes ranging from 1/3 to several hundred Hp. The 1 Hp and larger three-phase motors are less expensive than single-phase motors. Applications are on large pieces of equipment.

The following illustrations show wiring diagrams for a three-phase motor operating in both directions. Three-phase motors may be "delta" or "wye" connected and can be single or dual voltage.


3-PHASE MOTOR CONNECTED TO A 3-PHASE POWER SUPPLY
3-PHASE POWER SUPPLY
STATOR FIELD WINDINGS
3-PHASE MOTOR CONNECTED FOR REVERSE ROTATION
3-PHASE POWER SUPPLY
STATOR FIELD WINDINGS
TO REVERSE DIRECTION OF ROTATION, INTERCHANGE ANY 2 MOTOR LEADS.

6. MOTOR DRIVES

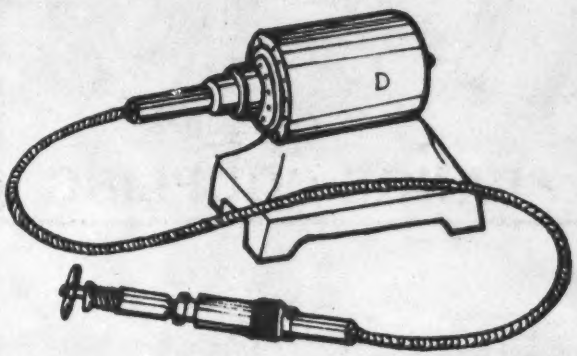
Machinery and equipment driven by electric motors are operated at different speeds. For the machine to operate efficiently, it must be driven at a specified speed; therefore, before selecting an electric motor and the drive, the operating speed of the machine should be determined.

In the selection of a drive, two factors are considered: (1) operating speed of equipment, and (2) size of drive. The operating speed of newly purchased equipment should be relatively simple to determine, since an operator's manual generally accompanies the equipment. A nameplate or some other source might provide this information for used equipment.

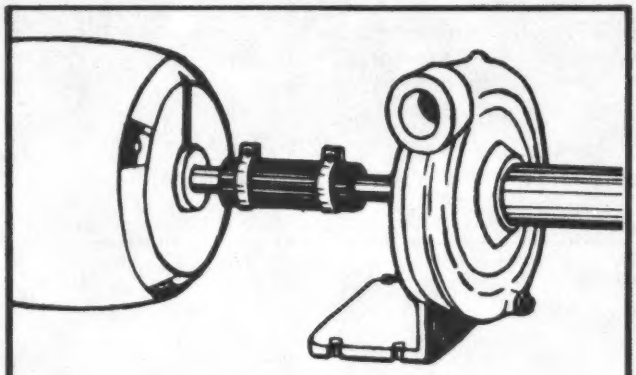
The size of drive for a machine is not as critical as the operating speed, but the drive should be large enough to pull the load efficiently. Drives may be classified into two general types, which are (1) direct and (2) speed-conversion (belts and pulleys).

A direct drive is a motor connected directly to a machine. The machine operates at the same speed as the motor. There are four kinds of direct drives. These are (1) flexible shaft, (2) flexible hose, (3) cushion-flange coupling, and (4) flange coupling.

Flexible Shaft Drive - Used on equipment operating at various angles. Examples are buffers and grinders. Since flexible shafts are manufactured to operate in only one direction, the direction the shaft is to be operated (clockwise or counter-clockwise) should be specified when the shaft is purchased. The machine with this type is operated at the same speed as is the motor.



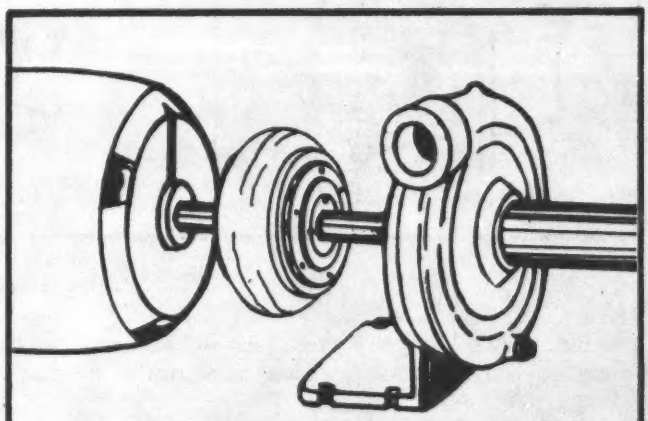
FLEXIBLE SHAFT



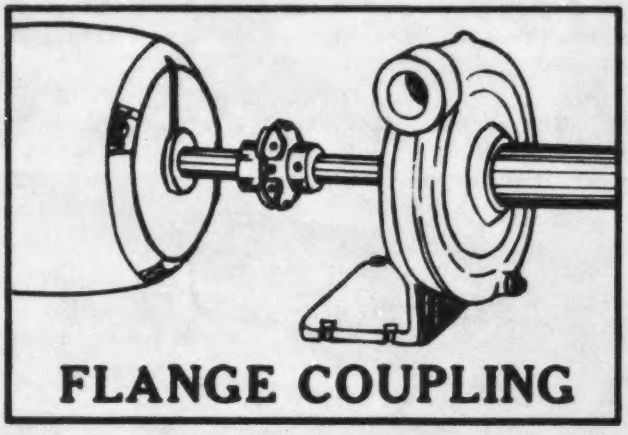
FLEXIBLE HOSE COUPLING

Flexible Hose Coupling Drive - A piece of plastic or rubber hose is used as the drive. The ends of the hose are forced over the ends of the machine and motor shaft and are held in place with clamps.

Cushion-Flange Coupling Drive - This type consists of two flanges, which are attached to the shafts, and a flexible center part, which is fastened to the flanges. A flexible action is furnished by the center part which is made of rubber or a similar material.



CUSHION-FLANGE COUPLING



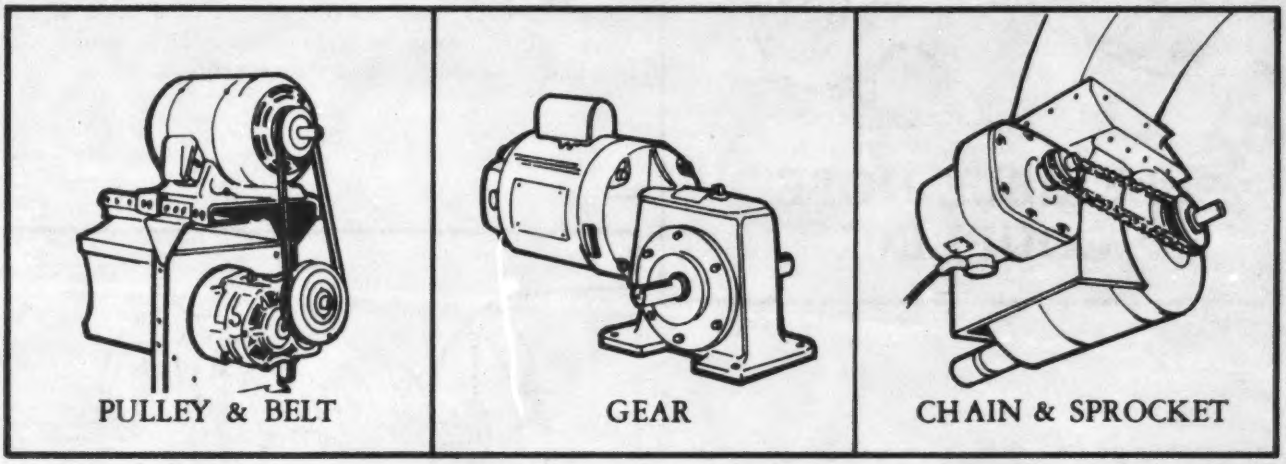
FLANGE COUPLING

Flange Coupling Drive - Two metal discs and a flexible middle disc are components of this type. The metal discs are fastened to the motor and machine shaft, and the middle disc is placed between the metal discs. The parts are then fastened together.

Speed Conversion Drives

These are used to drive equipment and machines at a speed which is different from that of the motor furnishing the power. The three types of speed conversion drives are (1) pulley and belts, (2) gear, and (3) chain-and-sprocket.

Since the gear and chain-and-sprocket drives are generally included as a part of the machine to be driven and are very complex, and since the pulley-and belt drive is most often used on the farm, it is the only one discussed.



PULLEY & BELT

GEAR

CHAIN & SPROCKET

Pulley and Belt Drive

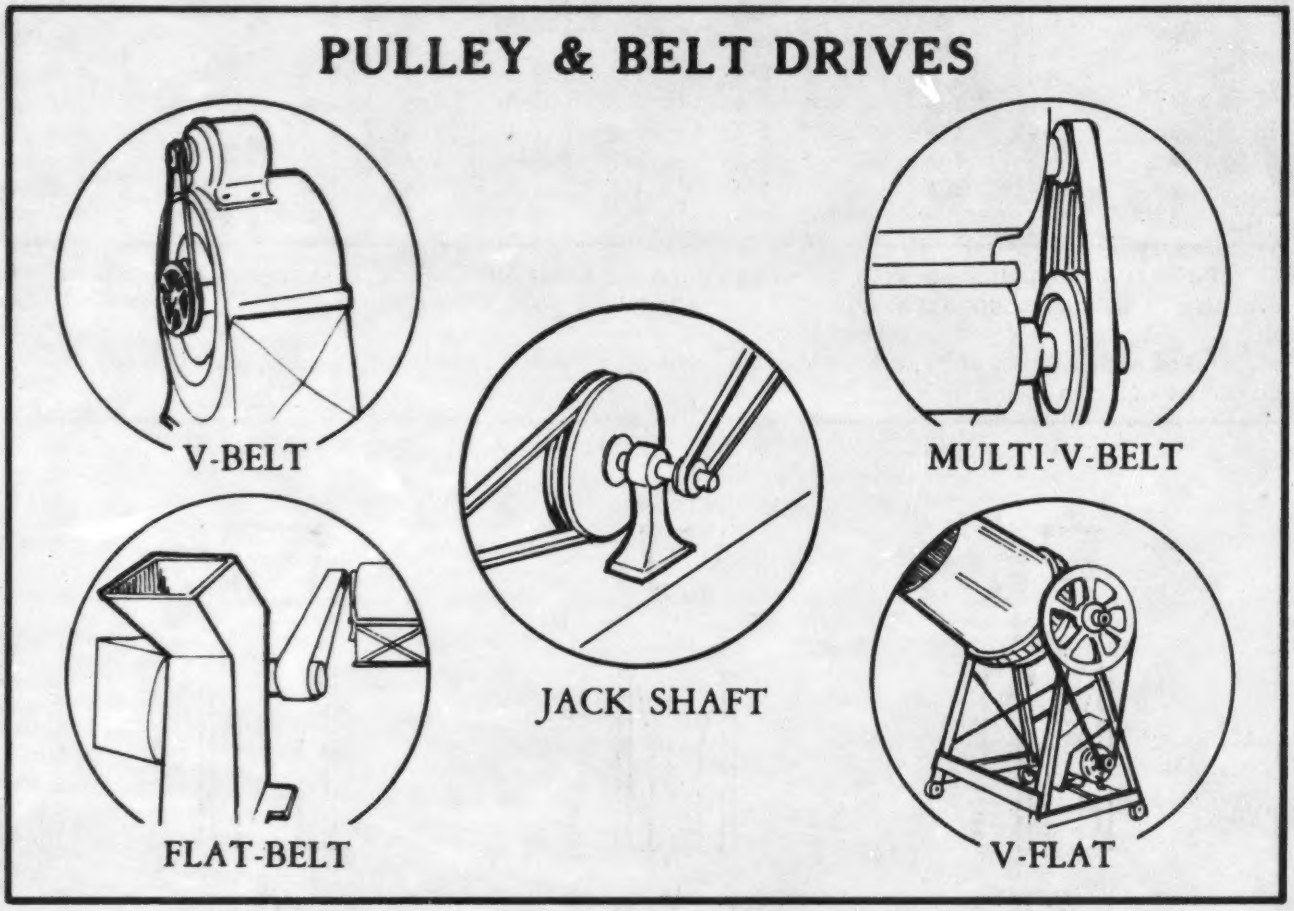
The pulley is a very important part of the driven system. Generally, the larger the pulley, the better, because less slippage occurs when more pulley area is in contact with the belt.

To prevent slippage, a pulley at least two inches in diameter should be used on motors of 1/2 Hp or less. If belt slippage will not affect the operation of equipment, a smaller diameter pulley may be used. For motors larger than 1/2 Hp, a three-inch diameter pulley is recommended.

A jack shaft (shaft with a pulley on both ends) is recommended as a part of the drive for equipment designed to operate at less than 200 rpm. It is recommended that the pulley connecting the jack shaft to the motor be 12 inches in diameter.

The four types of pulley-and-belt drives are (1) V-belt, (2) webbed multi-V-belt, (3) flat-belt, and (4) V-flat drive. A discussion of each type follows:

V-Belt Drive - This is the most popular drive used with electric motors. It has several advantages: The motor may be mounted on or close to the machine, and less tension is needed on the belt because of the wedging action of the belt and the pulley groove. Also, the belt stays on the pulley better.



Common V-Belts and Pulleys

Three sizes of V-belts are normally used on farms. These are the fractional-horsepower (FHP), A-section, and B-section.

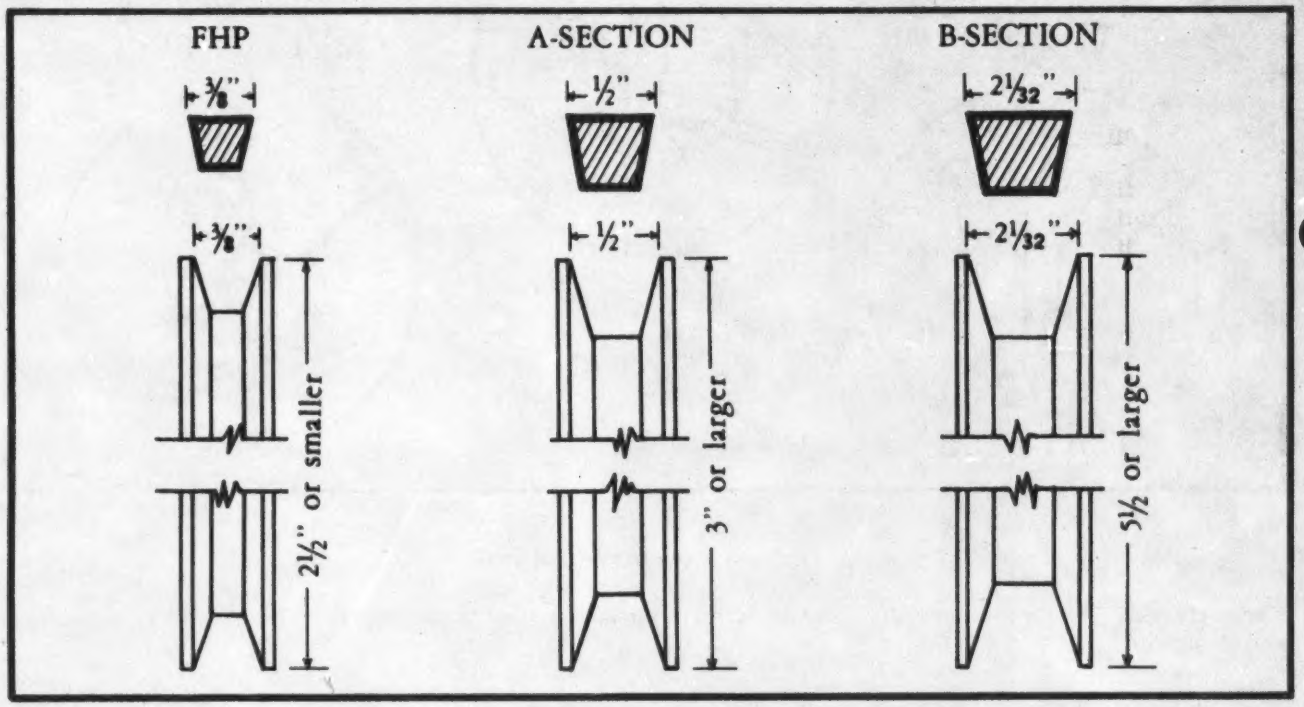
The FHP is suited for pulleys 2 1/2 inches and less in diameter. They are thinner and much more flexible. The A-section V-belt is heavier and can be used on small pulleys, but there is more slippage than the thinner belt. The stiffness of the belt prevents it from following the curvature of the pulleys. It is designed for pulleys three inches in diameter or larger.

B-section V-belts are designed for use on motors of 3 Hp or larger. The motor pulley should be 5 1/2 inches or larger in diameter.

Number and Types of V-Belts Recommended for 1750 RPM Motors								
Diameter of Motor Pulley in Inches	Size of Motor (Horsepower)							
	1/2 or Smaller	3/4	1	1½	2	3	5	7½
2	FHP*	FHP*						
3	1-A	1-A	1-A	2-A	2-A	3-A	5-A	8-A
4	1-A	1-A	1-A	1-A	2-A	2-A	3-A	5-A
5	1-A	1-A	1-A	1-A	1-A	2-A	3-A	4-A
6	1-A	1-A	1-A	1-A	1-A	1-B	2-B	2-B
7	1-A	1-A	1-A	1-A	1-A	1-B	2-B**	2-B
8	1-A	1-A	1-A	1-A	1-A	1-B**	1-B	2-B

*FHP- (Fractional Horsepower) a belt designed for small pulleys and small motors. Most commonly available in 3/8 inch width but also available in 1/2 and 5/8 widths.

** The same number of Type A belts could be used instead of Type B. On multiple belt drives, all belts should be replaced at one time.



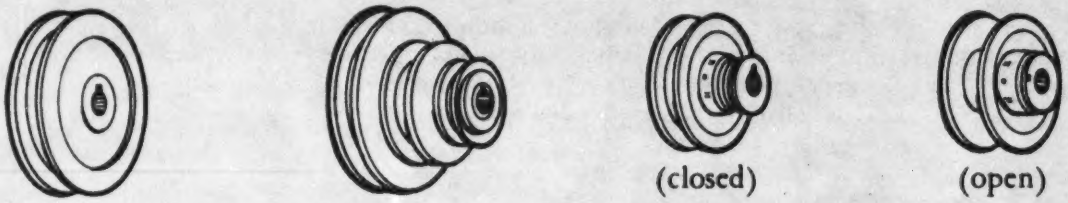
Webbed Multi-V-Belt - Two or more V-belts webbed together make up this type. Its main advantages are the elimination of slippage and belt turnover.

Flat-Belt - The flat drive consists of a flat pulley on the motor, as well as one on the machine being driven. This is used for motors located some distance from the machine. A feed grinder is an example. A pressed-paper pulley should be used for high speeds, while steel, wood, or cast iron pulleys may be used for slow speeds. The most popular flat belts for farm use are made of rubber.

V-Flat Belt Drive - This type consists of one or more V-belts, one V-pulley, and one flat pulley. This system is recommended for machines with pulleys larger than 12 inches in diameter and operated at 600 rpm or less. The distance from the center of the motor pulley to the center of the machine pulley should not be greater than the diameter of the equipment pulley. Following this recommendation will prevent belt slippage.

Many of the farm motors are fractional-horsepower and require only a single V-belt to drive the machine. Three types of V-pulleys are available. These are the standard V-, V-step, and adjustable V-pulleys. The standard V-pulley is used when only one speed is needed, while the V-step pulley is used for machine driven variable speeds, such as would be used on a drillpress. The adjustable V-pulley is also for variable speeds. The diameter of the pulley may be increased or decreased to adjust the speed to the desired rpm.

V-PULLEYS



STANDARD V-STEP ADJUSTABLE

Determing Belt Length

To determine the length of a V-belt for a mounted motor, a piece of string is looped around and in the grooves of the pulleys, pulled tight, and a knot tied in ends of the string. The string is cut, and its length is measured. This gives the inside length of the belt needed.

The following procedure may be used to determine the size of belt to use for an unmounted motor:

4 x diameter of largest pulley _____
1.6 x diameter of motor pulley _____
1.6 x diameter of machine pulley _____
Total length _____

Example: Motor pulley 3 inches, machine pulley 6 inches

4 x 6 = 24.0 inches
1.6 x 3 = 4.8 inches
1.6 x 6 = 9.6 inches
Total 38.4

The closest standard length belt to the above measurement should be purchased, and the motor should be mounted at a distance from the machine shaft to provide adequate tension on the belt.

Pulley Size Formula

RPM of Motor	X	Diameter of Motor Pulley	=	RPM of Machine	X	Diameter of Machine Pulley

In the following example, the size of pulley needed to turn a fan at 875 rpm is determined. The fan is driven by a 1/3 Hp electric motor which operates at 1750 rpm and has a pulley two inches in diameter.

Step No. 1 - 1750 x 2 = 875 x Dia. Machine Pulley

Step No. 2 - $D = \frac{1750 \times 2}{875} = 4$ inches - pulley diameter needed on machine

The following is the procedure to use to determine the diameter of pulleys needed on a motor, jack shaft, and machine when this drive system is used.

In the following example, it is assumed that the machine should operate at 60 rpm and the motor speed is 1750 rpm.

Previous recommendations were that a two-inch pulley be used on fractional-horsepower motors and that the jack shaft have one pulley 12 inches in diameter.

Step No. 1 - Calculate speed of jack shaft. The following formula is used:

rpm (motor) x D (motor pulley) = rpm (jack shaft) x D (jack shaft pulley)

1750 x 2 = rpm (jack shaft) x 12

$$\text{rpm (jack shaft)} = \frac{1750 \times 2}{12} = 292 \text{ rpm}$$

Step No. 2 - Determine size of pulley for machine

292 rpm x diameter (other jack shaft pulley) = 60 rpm x D (machine).

A two-inch pulley is tried for the other jack shaft pulley 292 rpm x 2 in. = 60 rpm x D (machine pulley) Diameter of machine pulley = $\frac{292 \times 2}{60} = 9.8$ or 10 inch pulley is needed for machine.

7. MOTOR PROTECTION AND MAINTENANCE

Overload Protection - An electric motor should be protected from performing more work than it is designed to perform. If the motor is overloaded, the ampere flow is likely to become great enough to damage the motor.

An overload can be caused by (1) motor size too small for the job, (2) improper wiring and low voltage, (3) improper installation, (4) belts too tight, (5) improper lubrication, or (6) the entry of foreign materials (dust, water, or oil) into the motor.

Overload protection may be provided by (1) proper fusing of the motor circuit, (2) built in protection in the motor, (3) manual reset switch control, or (4) special motor starter (current-limiting starter). The proper fusing of the motor circuit is discussed in the topic on electric wiring.

Proper Installation - The installation of an electric motor should be made so that a minimum of vibration will occur. It is also very important to make the installation so that proper alignment will result. Misalignment will cause wear and may also be a factor in overloading a motor.

Prevent Friction - A minimum of friction in the mechanical operation of a motor is necessary to prevent excessive wear and possible overloading of the motor. The manufacturer's recommendations for lubrication intervals should be closely followed. A high-quality lubricant should be used for motor lubrication. Motors with sleeve bearings require mounting so that the shaft is horizontal and level for proper lubrication.

Worn bearings should be replaced and the alignment of motor, drive, and equipment should be true.

Protect From Excessive Oil - Too much oil or grease can be harmful to an electric motor. Damage from too much oil may result from the accumulation of extra dust or from the deterioration of insulation within the motor. The manufacturer's recommendations for lubricating a motor should be closely followed. To remove excessive oil, a non-inflammable solvent and a paint brush may be used.

Protect From Dust - The accumulation of dust in and on a motor acts as insulation and may cause excessive heating of the motor. Dust and other foreign materials counteract lubrication and will cause friction and wear in the bearings and shaft.

The dust should be wiped from motors at regular intervals. Air under pressure (not more than 40 pounds per square inch pressure) should be used to blow dust from the windings at regular intervals. Excessive lubrication should be avoided to prevent excessive accumulation of dust. Dust seals and oil caps on motors should be in good condition and kept closed.

Protect From Moisture - Moisture is a conductor of electricity. Dry insulation confines the current to the correct path. When insulation is wet, the current may not be properly confined and a "short" may result. Motors may be protected from moisture by well-ventilated enclosures. A wet motor should be dried thoroughly before it is used. Some type of heat and a fan may be applied to the motor to dry it thoroughly.

SUGGESTED STUDENT ACTIVITIES

I. Fill in the blanks

1. A _____ electric motor can do physical work equal to approximately 2 1/2 men.
2. The efficiency of electric motors varies from _____ to _____ percent.
3. To estimate power consumption of motors up to 1 Hp, figure _____ watts per horsepower, and for motor sizes 1 Hp and larger, _____ watts per horsepower may be used.
4. If a gasoline engine is to be replaced by an electric motor, the electric motor should be approximately _____ the Hp rating of the gasoline engine.
5. The four most common types of enclosures for farm electric motors are: _____, _____, _____, and _____.

II. Discussion questions

1. Explain the advantages of electric motors.

2. Discuss the selection of electric motors.

3. Explain the application of the motor nameplate information.

4. Discuss factors that relate to motor protection and maintenance.

III. Problem solving

1. Figure the cost of pumping 4500 gallons of water with a 1/4 Hp motor if it pumps 500 gallons per hour and electricity costs 6¢ per KWH.

2. Determine the pulley size needed to turn a fan at 875 rpm. The fan is driven by a 1/3 Hp electric motor which operates at 1750 rpm and has a 2 inch diameter pulley.

3. Calculate the belt length for a 3 inch motor pulley and 6 inch machine pulley.

IV. Compare the following electric motors by completing the chart.

MOTOR TYPE	STARTING ABILITY	STARTING CURRENT	HORSEPOWER RANGE	VOLTAGE	USES
Split Phase					
Capacitor-Start					
Repulsion-Start					
Universal					
Shaded-Pole					
Three-Phase					

V. True or False

_____ 1. Motor drives are classified into two general types, direct and speed-conversion.
_____ 2. Direct drives may be flexible shaft, flexible hose, cushion-flange coupling, and flange coupling.
_____ 3. The three types of speed conversion drives are pulley and belt, gear, and chain and sprocket.
_____ 4. The V-belt drive is the least popular drive used with electric motors.
_____ 5. The FHP belt is designed for small pulleys and small motors.
_____ 6. On multiple belt drives, all belts should be replaced at one time.

VI. Diagram the procedure for testing continuity and reversing a single-voltage split-phase motor and a dual-voltage capacitor-start motor.

VII. Additional Student Activities

1. Test continuity on available electric motors.
2. Determine running and starting windings on available electric motors.
3. Change voltage on available electric motors.
4. Reverse direction of rotation on available electric motors.
5. Disassemble and reassemble available electric motors.